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JOHN C. TRAUTWINE, JR., *Secretary*, 257 S. FOURTH STREET, PHILADELPHIA.

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ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated. Names of authors of papers, etc., are printed in *italics*.

NOTICE.

The Experimental Filter Plant at Pittsburg.

In publishing this paper in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for November, 1900, the statement should have been made that the author, Mr. Morris Knowles, is a member of the

Boston Society of Civil Engineers,

and that the paper was read before that Society June 20, 1900. The omission of this statement arose from oversight in this office.

JOHN C. TRAUTWINE, JR., *Secretary.*

Editors reprinting articles from this journal are requested to credit both the JOURNAL and he Society before which such articles were read.

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AUTOMOBILE VEHICLES.

BY PROF. LOUIS DERR, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[Read before the Boston Society of Civil Engineers May 16, 1900.*]

FIVE years ago there were not thirty practicable automobile vehicles in the world, and three years ago this number would have covered those in the United States. Up to September 1, 1899, the capitalization of companies formed for manufacturing automobiles was $406,945,000, not including an additional million for the manufacture of specialties or for operating. A great industry has been created out of nothing, resembling in rapidity of growth the electric railway, and without a doubt destined to exert as important an influence on transportation interests.

The problem confronting the automobile builder is to apply to the frame of a road vehicle a motor of sufficient power and endurance, under absolute and quick control and free from liability to accident or failure. It should be simple, easy of repair and capable of satisfactory operation without technical training on the part of the driver. Renewals of energy should be readily obtainable, and at a moderate cost. But the attempt to solve, even approximately, the problem stated in these requirements is a matter of extreme difficulty, and a complete solution cannot yet fairly be said to have been found. The problem has been approached from a number of sides, and the purpose of this paper is to present a brief discussion of the various methods by which vehicles of the present moment are propelled.

Existing types of motive power may be classified as follows:

*Manuscript received June 13, 1900.—Secretary, Ass'n of Eng. Socs.

1. Electric motors.

2. Internal combustion engines.

3. Engines driven by a gaseous pressure, including (a) steam engines and (b) vaporization engines, utilizing hot water under pressure and liquefied gases.

4. Combination types, usually an electric motor and internal combustion engine. Not very successful.

The electric motor, as applied to automobiles, presents virtually the problem that has already been solved for the street railway, and is now a very satisfactory piece of apparatus. It is usually of the four-pole enclosed type, series-wound, of high ratio of copper to iron and of great overload capacity. Fig. 1 shows a Riker motor. The motor is driven by current from a battery of

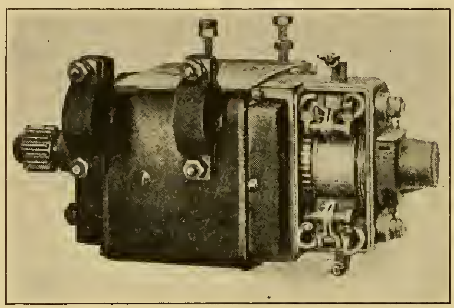


Fig. 1.

40 or 44 cells for the usual conditions of charging from a 110-volt circuit. The speed control is partly by dividing the battery electromotive force into halves or quarters, and partly by varying the strength of the motor fields. Either one or two motors may be used, and no starting rheostat is necessary.

The chief objections to the electric vehicle arise from the storage battery. After forty years of experimenting, the best types of battery for vehicles are now made of the "formed" type, just as were Planté's cells in 1860. The layer of active material on the surface of the positive plates is formed by repeated charging and discharging, instead of the shorter process of "pasting" on the plates a lead salt which is then changed to the active peroxide by a single charging. The latter type is cheaper, but, under the severe usage, fails rapidly. The most efficient batteries give an output of 3.5 to 6 watt hours per pound—from 125 to 213 pounds of battery per horse-power hour; but, as this weight is prohibitive, a lighter and less durable battery is used. The Columbia batteries give 3.8

ampere-hours per pound, or about 8 watt-hours. Batteries have been built claiming 10 or more watt-hours per pound, but they are probably of very short life. The average efficiency of batteries in automobile service is low, and the depreciation very high. A series of tests instituted by the Automobile Club of France showed an average efficiency of only 62 per cent., and of the eighteen batteries entering the competition only eight survived the sixtieth discharge.

The advantage of the electric vehicle is its simplicity and ease of operation; it would be difficult to devise anything simpler than the controller handle. A minimum of noise, no smoke or odors and immediate availability of the power complete the list of desirable qualities. But the weight and expense are serious matters. Energy for propulsion may be taken as averaging 120 watt-hours per ton-mile for good roads, and the battery furnishes about half of the total weight; whence the minimum battery for a given radius may be quickly calculated. The great weight is destructive to pneumatic tires, and is with difficulty hauled over grades. Since the motors are series-wound, there is no way of recovering even a fraction of the energy expended in climbing a grade by recharging the batteries during the downhill run. The disadvantages are therefore expense of maintenance and high first cost, as well as limited radius of travel unless suitable recharging stations can be found along the route. It is only fair to say, however, that the cost of battery renewals in one case is given as three-quarters of a cent per mile, and the cost of charging current $1\frac{3}{4}$ cents.

The internal combustion engine for automobiles has been highly developed in France, but as yet has not found extended favor in this country. In this type of motor the propelling impulses are furnished by the very rapid combustion or "explosion" of a mixture of hydrocarbon vapor and air in a cylinder behind a piston. Since there is no way of protecting the piston rod and glands from the intense heat of the combustion, such engines are necessarily single-acting from the opposite side of the piston. The cycle of operations is as follows: A forward stroke draws into the cylinder a quantity of the explosive mixture, and on the return stroke the charge is compressed. At or near the end of the stroke the mixture is ignited, and the pressure developed by the explosion drives the piston through the second forward stroke. At the end of the stroke the exhaust valve opens, and the burnt gases are pushed out of the cylinder on the second return stroke.

There is thus but one working stroke in four during the above or Otto cycle, and the engine must therefore be larger than one of the same power in which each stroke is a working stroke, as in the

steam engine. The shock accompanying the explosion requires a more substantial construction than would otherwise be necessary, and the high speed at which such motors must be run to develop sufficient power in small weights renders careful balancing imperative to prevent excessive vibration. In small sizes the cylinder may be kept sufficiently cool by providing it with projecting ribs to increase its radiating surface (see Fig. 2), but in engines of over 4 horse power a water jacket is necessary. The water is in turn cooled by circulation through a cooler composed of ribbed tubes and exposed to a draft of air.

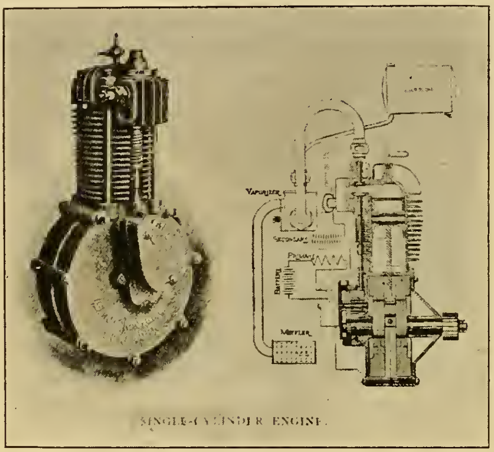


FIG. 2.

The original open-flame method of igniting the charge has been superseded by the hot tube method, and this in turn is being displaced by the electric spark. The former method requires a tube of nickel or other refractory material, closed at the outer end and heated to dull redness by a flame. The open end of the tube communicates with the cylinder, and the heat ignites the compressed charge. This has proved somewhat unreliable, and at present most engines are ignited by an electric spark. This is produced by an induction coil or similar apparatus, the spark points consisting of a pair of platinum wires projecting through an insulating plug into the cylinder.

The objections to the explosion motor for automobile service are its complexity and—thus far at least—its unreliability. The latter is almost wholly due to the ignition apparatus, and it is interesting to note that both methods of ignition are now used on French racing carriages. The motor is not self-starting, and a special

starting gear must be provided. The same is true for changing speeds and backing, both of which are usually accomplished by gear trains, although belt transmission is also used. The vibration of the engine is also a difficulty not easily overcome. Minor causes for criticism are the loud noise of the exhaust, even when a muffler is used, and the odor which is left for some time in the track of the machine. On the other hand, the speed and endurance of vehicles of this type far surpass anything that has as yet been obtained by other constructions, and they are therefore pre-eminently fitted for racing and long runs. A tricycle fitted with a motor of this type (see Fig. 3) has covered 45 miles within the hour, portions of the

FIG. 3.

distance at speeds greater than 60 miles per hour; and the limit seems to be only in the physical endurance of the rider and the heating of the pneumatic tires.

As might be expected from the time during which the steam engine has been a practicable prime mover, the steam-driven automobile has a lengthy history. In 1769 Jean Francis Cugnot built a steam-propelled gun carriage, using an internally fired kettle-shaped boiler and an engine connected to the driving wheels by a ratchet and pawl mechanism. Development was very slow, however, and in England was entirely stopped by restrictive legislation and in America by the absence of good roads. The removal of legislative restraints in the one country and the appearance of satisfactory highways in the other have greatly stimulated invention, and the result is a considerable number of steam vehicles both for light and heavy service.

The steam carriage for pleasure may be best discussed by describing a type now extensively exploited in this country (see Fig. 4). This carriage has a small upright fire tube boiler, holding six or seven gallons of water and weighing about 100 pounds. The fuel is gasoline, stored under air pressure in a supply tank. After vaporization by passing through heated tubes it is blown through a burner, taking up in its passage air enough to insure proper combustion. Automatic arrangements shut down the fire when the steam pressure reaches the predetermined limit. The engine is double, of the marine type and is connected to the driving wheels by a chain gear.

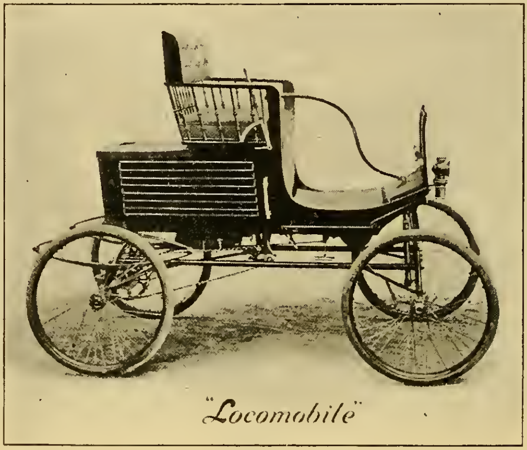


FIG. 4.

The small size of the reciprocating parts renders the engine vibration insignificant, and the carriage makes but little noise. A further advantage is its lightness, a carriage for two persons weighing, when fully equipped, only about 600 pounds. Its endurance depends, of course, on the size of the fuel and water tanks, but may be set as 20 or 30 miles for one filling. The great advantage of motors using naphtha or gasoline over storage batteries is that a new supply requires only a few minutes' time, and is readily obtainable. Low first cost, small operating expense and comparative simplicity of construction are further items that have contributed much to its popularity.

The steam carriage, however, is by no means free from objections. In starting or after long stops time is required to raise steam, and on the road a considerable fire is burning, supplied by the most inflammable fuel under pressure. This is a source of possible

danger that should not be forgotten. The small size of the boiler and its very great steaming capacity make a frequent inspection of the water-glass an essential part of the driver's duties; and in general it may be said that the steam carriage requires more care on the road than any of the types previously described. A minor objection is the visible exhaust in cold weather. Apparatus for condensation, if effective, is too cumbrous to be satisfactory.

The small size and method of construction of the boiler render accident from explosion unlikely, but the water level must be rather closely watched to prevent burning the tubes by the intense fire. A type of boiler is coming into use known as the "flash boiler," in which there is very little water, only as much being injected as is required by the engine, stroke by stroke. This boiler, developed by

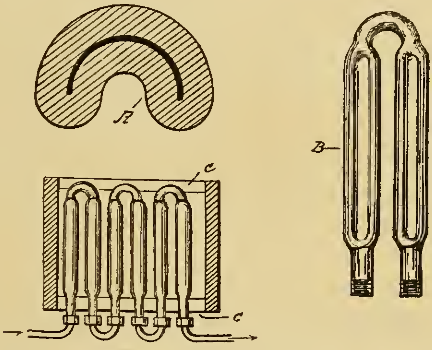


Fig. 5.

Serpollet in France, and commonly known by his name, consists of a series of tubes of very narrow cross-section, heated to a high temperature by the furnace gases. Fig. 5 shows the section and assembly of a Serpollet tube. The tubes vaporize the water almost instantly, and can be heated red hot without injury. It is evident that the water supply must be automatic and exactly proportionate to the consumption of steam. This requires reliable feeding devices. The tubes are short-lived but inexpensive, and their thickness, combined with the small amount of water in the boiler, makes explosion practically impossible.

Compressed air has been the engineer's dream ever since the invention of the steam engine, and many attempts—for the most part futile—have been made to apply it to vehicle propulsion. The chief trouble is from the inevitable refrigeration accompanying expansion, which, without reheating devices, quickly clogs the exhaust passages with frost; but, even apart from this, the energy stored in compressed air is really comparatively small. It can be shown by

a simple calculation that a pound of air, expanding isothermally from 150 pounds gage pressure to 15 (11 atmospheres to 2), will develop 48,300 foot pounds of work. Assuming that the steam carriage already described will develop 2½ horse power hours before exhaustion of water supply, it follows that 103 pounds of air will be needed for the same endurance under the given conditions, which, by the way, are beyond the possibility of realization in practice. At the given pressure the air would occupy 122 cubic feet, and a tank nearly 5 feet cube would be needed. As this is out of the question, a much higher compression is used, and the customary pressure is 2200 pounds, or about 150 atmospheres. This reduces the volume to 9 cubic feet. Steel reservoirs to withstand this pressure weigh about 85 pounds per cubic foot of capacity. A weight of 66 pounds has been realized, but in this case the factor of safety is rather small, and explosion of a tank under this pressure is highly dangerous. Thus to contain the air 765 pounds of reservoir will be needed. To have 165 pounds pressure at the end of the run another pound of air will be required, making a total of 869 pounds for reservoir and contents. This may be instructively compared with the 240 or 250 pounds required by the steam carriage for fuel, water and boiler. The weight of engines and piping is assumed to be the same in the two cases.

In practice the case is not quite as favorable for the air engine. Available data indicate that by using compounding, reheaters, etc., —all adding weight and complication—about 0.27 of a horse-power hour can be obtained from a cubic foot of air at 2000 pounds pressure. This weighs nearly 11 pounds, whence to get 2½ horse-power hours 118 pounds of air will be required. In the table below the available energy of compressed air expanding without loss under different pressure conditions is given for the sake of comparison with other sources of power.

In this connection it may not be out of place to call attention to the ludicrous claims put forward for the energy available when liquid air is vaporized. Of course the only reason for employing liquid air is the fancied possibility it offers of carrying the equivalent of a large amount of gaseous air without pressure. By noting that about 800 volumes of free air are required to produce one volume of liquid air, the energy of a pound of the liquid may be easily calculated. If vaporized in a closed tank the pressure would rise to 800 atmospheres, or, roughly, 12,000 pounds per square inch. Assuming that the total energy can be realized in isothermal expansion, there would still be demanded 10.5 pounds of liquid per horse-power hour, or, in other words, a gallon of liquid air repre-

sents a maximum of only three-quarters of a horse-power hour, an amount by no means difficult of comprehension.

The following table presents at a glance the previous results, and shows clearly the reason for the extraordinary endurance of the internal combustion engine:

	Foot Pounds per Pound of Medium.	Pounds per Horse Power Hour.
Light storage battery	15,000	132
Steam in small engine	49,500	40
Air expanding isothermally from 165 to 30 lbs	48,300	41
Air expanding isothermally from 165 to 15 lbs	69,400	28.6
Air expanding isothermally from 2200 to 15 lbs	137,000	14.4
Air expanding isothermally from 12,000 to 15 lbs	188,000	10.5
Air in perfect air engine, 165 to 15 lbs	48,700	40.7
Air in perfect air engine, 165 to 30 lbs	37,600	52.7
Air in perfect air engine, 2200 to 15 lbs	74,400	26.8
Coal, 14,500 B. T. U., in steam plant of 12½ per cent. total efficiency	1,410,000	1.40
Kerosene, 20,700 B. T. U., in internal combustion engine of 35 per cent. efficiency	5,590,000	0.354

The question of cost of maintenance, always an interesting one, has not yet been definitely settled for American conditions. The following table is for a carriage belonging to a French physician, and covers an experience of 6000 kilometers (about 4000 miles). It undoubtedly represents a fair average cost. Although in this country the fuel and lubrication cost would probably be smaller, and the writer's experience would incline him to reverse the proportion of repair and depreciation charges, the greater cost of tires for American roads would probably keep the total about the same. Of course, if the carriage is cared for by the owner the last item disappears:

Gasoline	2.00 cents per mile.
Oil and grease	0.15
Tires	0.94
Repairs and miscellaneous	5.05
Depreciation	3.09
Interest and taxes	1.09
Hostler	4.67
	16.99

In conclusion, it may fairly be said that the choice of type depends almost wholly on the character of the service. For urban passenger service, where recharging stations are conveniently accessible and frequent stops are necessary, the electric vehicle will probably hold its present supremacy for some time. For heavy service the steam car seems to be the most successful, and for high speeds and long runs the internal combustion motor at present shows a decided superiority over its less costly rival, the steam engine.

DISCUSSION.

Mr. John Balch Blood.—Liquid air has a latent heat of about 142 British thermal units. The power in steam has a potential energy due to heat difference between itself and the air. The steam has 966 latent heat units, and then we put in about 200 more, depending on the pressure, which makes about 1200. The difference of temperature of liquid air is not more than 300° or 400° below ordinary air. Taking 300 and adding it to 142 we have between 400 and 500. Hence, a pound of liquid air is only about half as good as a pound of steam. Neglecting the friction of the machine, steam compares with liquid air, as a refrigerative agent, in the ratio of about 500 to 1200. In other words, the thermal condition of liquid air is less removed from normal than is that of steam under pressure, in about the ratio of 5 to 12.

Let us look at this now with reference to two aspects,—namely, power and refrigeration.

First, with reference to power, it is evident that, with equal efficiencies of conversion, steam would be 2.4 times as good as liquid air per unit of weight.

The best we can do with steam is to utilize 200 B. T. U. per pound of steam, which would give an efficiency of the steam cycle of about 16 per cent. Therefore, liquid air must have at least 40 per cent. for efficiency of conversion to be on a par with steam.

We do not yet know what efficiency of conversion we do obtain, but, when we realize that we must expand from 12,000 pounds per square inch down to zero, we do not have a very bright outlook.

In New York, on the air power cars, they use 2000 pounds in the receivers and expand through two engines, and even then exhaust under pressure.

If the efficiency of conversion of liquid air were 100 per cent., the power obtainable would be only $2\frac{1}{2}$ times that of steam for a given weight. When you come to compare costs, steam is many times the cheaper, as no one has presumed to quote a price for liquid air that would compare at all with steam. Coal at $4.00 per ton is 5 pounds for one cent. If one pound of coal will evaporate 8 pounds of water we have 40 pounds of steam evaporated for one cent, or one pound of steam would stand at $0.00025.

For power purposes, therefore, if we assume that the conversion from liquid air is perfect (which we know is not a fact), liquid air must be sold at a price less than one mill per pound in order to compete with steam.

So much for the power aspect.

Second, with reference to refrigeration.

We saw above that liquid air had a negative temperature or refrigerative value of about 500 B. T. U. Ice has a latent heat of about 114 and a negative temperature of about 40°, which would give approximately a refrigeration value of 150 B. T. U.

It will be seen that for refrigeration one pound of liquid air is equal to 3.3 pounds of ice. If ice sells for 30 cents per 100 pounds, liquid air must sell at one cent per pound to compete.

PROFESSOR DERR.—In regard to compressed air automobiles, there is one industrial or economic consideration which should not be overlooked; that is, the danger, the positive danger, of carrying bottles of gases at a pressure of 2000 pounds to the square inch. I have often been questioned as to the danger to be feared in steam boilers carrying 200 pounds pressure, but no Board of Aldermen has objected to the steel air-bottle, although one of these bottles exploded of late, wrecking a stable and injuring six men rather seriously.

In answer to a question, Prof. Derr said: Heavy trucks, I think, ought to be safe to use. From the showing I tried to make in the table, the battle is going to be fought out between steam and gasoline, and, of course, if it is a question of steam, either some form of stored heat or liquid fuel will be used for urban service. Otherwise, I do not think the steam vehicle will be quite as much in favor as others. The heavy trucks, particularly the English ones, are invariably driven by steam; some of them are operated with solid fuel. The heavy gasoline engine is not yet a success.

The President then called upon Mr. Knight Neftel, manager of the New England Electric Vehicle Transportation Company, who spoke as follows:

MR. KNIGHT NEFTEL.—We are operating here and in Chicago, New York, Philadelphia and Washington a very large number of carriage batteries. In some cases we have used these batteries for three and four years, and our experience has been that the battery has given us less trouble and less cost for repairs than any other part. We have numbers of batteries that were installed three or four years ago, and I think the professor was mistaken when he said that there were only thirty automobiles in New York two years ago. We had more than this in operation in New York alone (electric), and these batteries are to-day in use in New York, the replacement of plates being a very small expense. The bad reputation that storage batteries have generally obtained may be explained by the statement that the manufacture of the reliable storage bat-

teries has been confined to one concern; those who have experimented with electric vehicles have not always been in position to obtain this make.

I hardly need say that the gasoline machine is not a vehicle for urban use. It is, as you have seen by the pictures, exceedingly complicated. It does not start easily; furthermore, it has the very great disadvantage of not being able to back unless it has a reversing gear, which is another complication not dwelt upon by Prof. Derr. The driver of an ordinary hack, cab or carriage for the transportation of passengers must be able to start up rapidly, or he will stall traffic. He must have absolute control of the vehicle in the method of starting, and he must also be able to reverse it instantly, if necessary to save life, and he must be able to back out of a tight place.

The electric motor gives, with a man of ordinary intelligence (such as it pays transportation companies to employ), that convenience and ease of operation which no other vehicle can give. Of course, the steam carriage can be reversed, but there are other difficulties with a large-sized steam vehicle which I need not touch upon to-night.

The greatest source of expense and of trouble to the automobile user is the tires; if he has a light vehicle, such as the locomobile, he meets with punctures, as on bicycles; if he has a gasoline vehicle, he wears the tires out; if he has an electric vehicle of greater weight, the tires are liable to explode. You have probably seen or heard these explosions on the streets here. The tire is the expensive part of the machine. The ingenuity of a great many men is engaged in remedying this difficulty, and we hope that some one will soon solve the problem.

The handling of the automobile business as a mercantile affair, with a company such as I am connected with, is a field which promises to be remunerative to capitalists and operators, and ultimately of great benefit to the public. It has required an enormous investment of money, and is still somewhat experimental. It has required the energy of a great many men to solve what may be called a great problem of organization. The handling of two, three or five hundred carriages of the various styles, dimensions, weights and capacities, entirely by mechanical means, and training men to take care of the mechanical system by means of which this is done, and finally the various trials and tribulations on the streets with the authorities and with the public, called for great expenditure of energy and of time by those who have promoted this enterprise in the different cities.

The result of one year's operation in Boston has been as follows: The present plant of our company has been in operation since October 2, so you will see that it is not yet a year old. So far we have traversed the streets of Boston to the extent of 112,000 miles, adding about 2000 or 3000 miles a day to this total. We handle, in storage batteries, from four to five hundred tons every day in our station. We operate about 154 automobile vehicles of various kinds, and we are adding about 60 more to be used for delivery wagon purposes. I am not referring to these things except to show you an interesting mechanical problem which is being worked out in this town, and of which, perhaps, many of you do not know.

For the charging of our batteries and the operation of this plant we are taking 100,000 kilowatt-hours of current per month, and I am happy to say that we are just getting clear of our pay rolls and other expenses. In other words, the service, I think, has proved popular with a great majority. There are some who do not like riding in these cabs, but, so far as we can judge, it is popular.

The delivery wagon part of the business is to me the most interesting, because that is simply a problem in transportation, where the vehicles are not confined to tracks and where we are filling a very large demand. We experimented with this at first, contracting to do the transportation on a limited scale for a large department store; after a short time it proved so successful—to them financially, and to us mechanically—that an arrangement has been made covering a period of years for the entire transportation of their sales.

Another experiment was tried in the delivery of newspapers; this has also proved so successful, so economical and such a saving of time, which is an item of importance to those concerned, that a still larger contract for a greater period has been entered into for the distribution of a large proportion of the newspapers from here to Roslindale and Dedham on the south, and to Lynn and Waltham on the north and west.

Other experiments have been tried here, in Philadelphia, in Washington and in New York, on other types of work of this kind, and in every case this feature has developed: that while there is no economy in supplying a man with one vehicle, there is a very large economy in supplying a man with ten vehicles. I now refer to the user. In other words, one vehicle will not compete with a horse, so far as economy is concerned, but ten vehicles will do the work of fifteen horse teams, not only more rapidly, but more satisfactorily.

It does not pay the small grocer, who has but one wagon, to buy, hire, rent or use an automobile, as one horse will be cheaper. But if he uses ten, twenty, forty or eighty wagons, the economy is very great and immediate.

I have intended to ask some of the engineers of Boston to visit our plant when completed, but we have been very much delayed in its completion. It is interesting and entirely different from anything ever attempted before on such a scale, and if, after the meeting, any of the gentlemen would like to look at some blue prints, showing the method of handling our batteries, I shall be glad to show them, and I hope the Society will accept an invitation and come and see our plant when in full operation.

Mr. Blood.—Mr. Neftel gives 500 tons of batteries for 154 vehicles, that is, two tons of battery handling a vehicle a little less than 20 miles a day; 3000 miles a day for 154 vehicles makes less than 20 miles a day. If the batteries would not do a great deal more than that they would be considered pretty poor batteries.

When you consider repairs on batteries compared with taxes, interest on investment and (in any mercantile enterprise) driver and caretaker, you will find that the depreciation account can be multiplied by four or five before it will come up to the other factors.

Mr. Neftel.—The gentleman is probably not aware that the battery has to be handled three or four times for every trip of the cab, and that the trip may be only a mile. If you will take my figures, 480 to 500 tons, figure out the number of batteries which that represents, and then try to find the mileage from that, you naturally will get extraordinary results. You would also get results which would be astounding if you were to figure how many times you have to handle the coal before it goes into the locomotive furnace, and how many miles this coal is transported before it is utilized, or some other such problem, but the coal has to be handled and so do the batteries.

If you call a cab from the Touraine and want to go to the South Union Station, we probably have to handle that battery four or five times; that is where the problem of mechanical handling comes in.

For pleasure vehicles, altogether a different field, entirely different batteries are constructed, such, for instance, as those used by Mr. Maxim, who made a run from Philadelphia to Atlantic City and return of over 110 miles and could have gone further.

When it comes to commercial, heavy, hard work, you must use low-capacity batteries, very heavy and very durable, and you will get good results. One more remark in reference to weights.

We have records of a large number of different vehicles. We run vehicles which are very light and we have records of mileage and repairs, and our reports are very accurately made daily, not only here, but all over the country. Besides, we operate trucks which will carry two tons at the rate of 10 miles an hour. We have found that the heavier the vehicle, the less are the repairs and the cost of operation, and the greater the durability. This is an actual fact, and I will be pleased to show you how much less it costs us, in repairs and in power, to push one of these Houghton & Dutton wagons, loaded, than it does to push a two-seated carriage. That is a very curious development, and that is the reason why we feel that the question of weight is not of such moment as many would make it. While a very light automobile buggy is the one that will fall apart first, the heavier one with wooden wheels has an excess of weight of material to prevent parts getting out of line, and other troubles, and is the one that will last the longest. A few pounds more or less amount to nothing as far as mileage is concerned.

Professor Allen.—I should like to ask the last speaker how far, for heavy work, he expects a battery to last between reloadings.

Mr. Neftel.—A battery could not run an ordinary automobile delivery wagon, with a load of one ton, more than 25 miles. Of course, the distance depends greatly upon the road. On a level road, under good conditions, with a standard storage battery, it should not be asked to drive more than 25 miles; one of Houghton & Dutton's vehicles will go 40 miles with two batteries in Boston and suburbs.

Professor Derr was asked whether the statistics he showed on the table, relating to a physician's carriage, referred to a French physician. He answered in the affirmative.

Professor Watson.—Suppose we were to take one of our vehicles, I do not mean a city cab, but one of the carriages which would be used in the country, say by a physician down on the cape who would have to go for miles around, or by a farmer who delivers produce, and who goes over country roads which are full of ruts. I always imagined that the natural tendency would be to get them as low as possible for the sake of lightness and cheapness. I suppose the expense for such a carriage would be very large.

Professor Derr.—I would be glad to furnish figures, but as far as I know none are in existence. If the French automobile estimate of 17 cents per mile is taken for a basis, the expense for such a carriage as the last speaker mentioned would be quite large.

The gentleman who spoke of storage batteries has not proved his case; my own experience is of the same kind. I have operated a steam carriage for 700 miles, at a total cost of repairs of 95 cents. If the cost of battery repairs and renewals can be correctly estimated from data obtained in operating heavy, low-capacity batteries, or even from the general average of a plant less than a year in operation, then it seems to me equally proper to estimate the cost of repairs to a steam carriage, such as the one mentioned, as one-seventh of a cent per mile, and the latter proposition would be quite difficult to establish.

AUTOMOBILES.

By Dr. T. J. Martin.

[Read before the Engineers' Society of Western New York May 7, 1900.*]

Ever since the discovery of steam power there has been a demand for self-propelling vehicles, and the present development can be traced from the road roller and bicycle to the advanced forms used for mercantile and pleasure purposes to-day.

Road motors attracted the attention of inventors as far back as the end of the last century, and in 1801 there was a steam carriage which would climb hills faster than a man could walk. Before inventive attention was turned to railroad development there were many attempts to perfect these road carriages.

From 1825-1835 the Squire carriages were running in England at an average speed of fourteen miles an hour, but these early attempts did not attain the excellence or cheapness necessary to create a demand among the masses for that form of locomotion.

This end of the century is a "rapid" one, and we are a "rapid" people who have created a demand for something not yet entirely developed, although we have three very satisfactory forms of self-propelling vehicles.

We require of the automobile that it be easily controlled, steered and stopped. It must have speed and abundance of power. It must be cleanly and not too noisy.

The real problem is, of course, which is the preferable power, looking at the question as it is developed to-day.

Let us consider the three motive powers in practical use to-day, with their comparative costs of operation, etc.,—viz, electricity, gasoline and steam.

Mr. Riker, in a recent address, gave a concise description of the batteries used in electric vehicles. He said:

"We do not require any change of gearing in the electric automobile to alter the speed or climb a grade, but accomplish this electrically by a series of switches, so grouped as to be operated by one handle, which is called the controller.

"From this controller wires lead to four groups of batteries and to the motor or motors, as the case may be. As the speed of an electric motor depends upon the pressure of the current supplied, you will at once see that change of pressure means also change of speed. This pressure, in technical language, is called *voltage*.

"As it is necessary when recharging the batteries to connect them to a direct current, each cell requiring about 2.5 volts, and as

*Manuscript received June 7, 1900.—Secretary, Ass'n of Eng. Socs.

the prevailing pressure is about 110 volts, it is necessary, if we desire to charge economically, to use from 40 to 44 cells of battery.

"These cells are placed in four crates or boxes, each holding ten cells. The cells in each crate are connected in series; that is to say, the positive terminal of one is fastened to the negative terminal of the next. As the pressure of a cell on this charge is about 2 volts, and there are ten in a crate, the pressure at the terminals of each crate is approximately 20 volts. Now, it is possible so to connect the four boxes that we obtain three pressures,—namely, 20 volts, 40 volts and 80 volts. In the first position the four crates are connected so that the motor receives a pressure of 20 volts. When they are connected in multiple each crate furnishes one-fourth the total current. For example, if the motor takes 20 amperes, each box is furnishing 5. This arrangement allows all of the cells to discharge at the same time. This method of control has another very advantageous feature. If one of the crates, say, for example, No. 2, should show signs of being discharged before the others, we may, by leaving the controller in the first position for a short time, make the other crates charge the weak one, and thus save those cells from overdischarge and possible injury. In the second position of the controller crates 1 and 2 are connected in series, as are also 3 and 4. These two sets are then grouped in multiple, and furnish a pressure of 40 volts to the motor. In this second arrangement only one-half of the total current is supplied from each crate; therefore, if the discharge is as before, 20 amperes, each crate or box is furnishing 10. We now come to position No. 3, which gives the greatest pressure we are able to produce. In this position all the crates are connected in series, and the pressure supplied to the motor is 80 volts,—20 amperes are furnished by each crate.

"As it is necessary to know how much electricity we have stored up, and how fast this is being consumed, we use a combined volt and ampere meter. I think at this point it would be well to explain that the difference in pressure between a fully-charged storage cell and the same discharged is about 0.3 of a volt, being 2 volts at the beginning and 1.7 volts at the end of the discharge. With 40 cells, the pressure at the start is 80 volts, which falls gradually to 68 at the finish. These meters are therefore marked in this manner: Opposite 80 volts the word *charged* is written, and *discharged* against 68. You can therefore spin along at ease until, while running on a level stretch of road at a normal discharge, your meter reads 75 volts. You know then that you have used half your charge, and that you must either return or find some

means of recharging. This device has been in constant use for over three years, and I have never known any one to run out of charge who was governed by the reading of the meter. I have so far explained only one side of the meter, and how it operates on discharge or the running of the carriage. It has still another function. When a storage battery is connected to a source of current to be recharged the back pressure of a cell is about 2.1 volts, making the 40 cells require 84 volts to recharge them. As they absorb the charge, their pressure gradually rises to 2.5 volts per cell, or 100 volts for the 40 cells, at which pressure the charging should be stopped, as the battery is full. The meter also indicates this condition. As it is also necessary to know at what rate to recharge the cells, the other half of the instrument is graded in amperes. This portion of the meter has a double scale, reading either the amount of current going into or out of the battery, enabling us to charge at the proper rate for the best results to the battery, and, when running, shows the amount of power being used. It is therefore possible, with an electric carriage and one of these meters, to know at any time just what horse power you are developing."

Gasoline, four-cycle operation:

"First stroke draws in a charge or mixture of gasoline and air; the next stroke compressing that mixture through a higher atmospheric pressure, varying from 40 to 70 pounds pressure; the next stroke being the useful stroke of the four, in which the charge is exploded and the piston driven forward.

"The fourth cycle is the one in which the exploded gases are expelled from the cylinder, and the cycle commences over again. Therefore, in a single-cylinder gasoline engine we have one useful stroke in four. Multiplying our cylinders, taking two cylinders, we have one useful stroke in each revolution. If we have four cylinders we have two useful strokes in each revolution, if they are properly proportioned and divided."

There are two classes of gasoline motors,—flange cooling and water jackets; vaporization, tank method vaporizer.

The steam carriages best known are the Overman, Crouch, Whitney, Locomobile.

The Overman has a steam boiler and a slide-valve engine. Steam is exhausted into the hollow tubes of the running gear, and passes into the atmosphere through small holes drilled in the front axle.

The Crouch carriage employs superheated steam. All these makes are of the same general kind, using a small boiler which is fired by gasoline.

In the Locomobile gasoline is used as a fuel; the tank is under the footboard. Fuel is forced by compressed air through the boiler, where it is vaporized, to the burner, where it is ignited. The power is obtained by means of a chain from the engine sprocket to the sprocket on the rear axle.

DISCUSSION.

Mr. Guthrie.—Has the weight of the automobile increased or lessened?

Dr. Martin.—It has increased. It has been found, by actual experience throughout this country and Europe, that to obtain satisfactory commercial results all manufacturers were obliged to guard against one common enemy,—namely, crystallization of metal. Automobiles are invariably built for speed. Speed in turn, on the average American roads, means violent vibration. This vibration is intensified at those points about the machine which carry the maximum weight at an angle, such as pivot axle, steering arm, rear axle, near the bearings, etc. All electric machines carry a storage battery varying in weight from 500 to 1800 pounds. The bulk of this weight is in the lead plates. The first carriages built by the Pope Manufacturing Company weighed about 1600 pounds (battery included). This same type of machine (Mark III) to-day weighs nearly 2600 pounds (battery included). The increase in weight is required, first, to meet the demand for increased mileage, and, second, to guard against crystallization. The machine weighing 1600 pounds had a 20-mile maximum capacity. The 2600-pound machine has a 35-mile capacity. A heavier and longer mileage battery requires, in turn, heavier and stronger parts of the machine. I have some very interesting specimens at our station of crystallization at these various points of the machine.

Mr. Guthrie.—Why is the automobile so expensive?

Dr. Martin.—The automobile must be an expensive product as long as it has not become standardized in its various parts. A visit to the motor vehicle factory reveals the fact that every bolt, nut, screw and everything else is turned out by day labor and lathe work; in fact, little is seen of an automobile until the "assembling" and finishing departments are reached.

Mr. Morse.—Which machine is liked the best here?

Dr. Martin.—In foreign countries, such as Germany, France and England, the gasoline machine is the favorite, for two reasons: First, the unlimited mileage permitting longer distances between points where charging stations could be established, and, second, the fact that gasoline is universal and cheap.

Europeans try to get away from the "horse carriage" idea. They demand a veritable machine, and when driving one for pleasure or business they dress accordingly; that is, they wear rubber coats, leather caps and "goggles," thus protecting themselves from grease and dirt. They go into it from a sporting standpoint.

In this country, where the art of manufacturing and running motor vehicles is comparatively new, the electric machine has the preference, because it is noiseless, clean, odorless and does not require a machinist to operate it successfully. The ease with which electricity can be obtained in almost any village is another point in its favor.

Mr. Guthrie.—What is the cost of maintenance?

Dr. Martin.—Permit me to use my own Columbia carriage (Mark III, Lot II) as an illustration. I have operated this carriage in this city for the past three winters and two summers, covering about 35,000 miles. It has never cost me over three-fourths of a cent per mile for current. The cleansing of the batteries costs about $25 a year. The cost of tires, one set per year, is about $80. Paint and varnish about $20. These are the principal items of maintenance.

Mr. Guthrie.—How many miles can you make per gallon of gasoline?

Dr. Martin.—I am not familiar enough with the actual manipulation of the gasoline machine to give you exact data. I can tell you only what claims are made in this country. Gasoline carriages usually carry from three to five gallons, which quantity, we are told, will carry the machine about 100 miles. I do not believe this, but I believe about 30 miles might be made on the average American road.

(Dr. Martin here cited the trans-continental experience of Mr. and Mrs. Davis, stating that one of the greatest difficulties they met with was the difficulty of keeping supplied with gasoline.)

The steam carriage has difficulties similar to those of the gasoline, and I consider this type of motor vehicle the most dangerous in the hands of any one except machinists and experts, for the reason, mainly, that in this type of vehicle we have a flame and burner within a few inches of the gasoline tank. They also readily take fire, or become enveloped in flame from a leaky gasoline tank or its connections. In cold weather the water gauges and pipe connections freeze; and most serious of all is the ease with which a boiler is "burned out," necessitating an expenditure of from $200 to $300.

This Columbia automobile rents for $250 per month with a driver, or $200 without the driver. Others rent for $150 to $200. This includes the repairs to the machine. We take entire charge of the repairs.

Mr. Guthrie.—I move that a vote of thanks be extended to Dr. Martin for his very able and interesting address on automobiles.

Seconded by Major Symons.

Carried unanimously. Applause.

A NEW RACK AND OTHER IMPROVEMENTS TO THE FEEDER FOR THE MIDDLESEX COMPANY, LOWELL, MASS.

By Arthur T. Safford, Member Boston Society of Civil Engineers.

[Read before the Society, April 11, 1900.*]

The Middlesex Company, for the purpose of obtaining 525 net horse power for its mills at Lowell, Mass., draws from the Lower Pawtucket Canal a little less than 300 cubic feet of water per second through an old wooden feeder 210 feet long, which delivers the water into two wrought iron feeders 18 feet long. These wrought iron feeders supply two Swain wheels, side by side, 66 and 72 inches in diameter respectively, which drive, through crown and bevel gears, onto the main shaft of the mill. A steam engine of 250 horse power is belted to this shaft, and was formerly used to augment the power; but, since the improvements of this past year have been made, it is possible to run the mill entirely by water.

Fig. 1 shows the conditions before making the improvements, the location of these wheels in the mill and the feeder and its relations to the canal. The general arrangement of everything, Fig. 2, remains the same now, excepting those changes described in this paper.

Previous to the work of this last year the water was drawn from the Lower Pawtucket Canal into the feeder through an old vertical wooden rack or screen 39 feet long and 8½ feet high, the top of the rack being above running mark in the canal; the slats of the rack were of wood, being of ⅞-inch stuff with spaces 1½ inches wide between them. A rack of this character is put in to keep leaves, sticks and other *débris* from getting into the wheels. The clear area through which water could go at the high running mark of the canal, when there were no local obstructions, was 200 square feet, or 60 per cent. of the superficial area of the rack; but one-quarter of the area of the rack, downstream from the head of the feeder, did not supply its proportional part of the water on account of the proximity of the wall behind the rack. The top of the rack was at high-water mark, and if the canal was drawn down, as it often is, a foot or more, the rack area was diminished about 12 per cent. At times when ice and snow were running in the canal the clear area of the rack was further considerably reduced, on account of the ice and snow being drawn towards the rack by the current. It required constant attention during the winter season, and kept

*Manuscript received June 7, 1900.—Secretary, Ass'n of Eng. Socs.

several men busy for a few hours each cold or snowy morning keeping the ice and snow from filling up the rack and shutting down the mill.

The velocity of the water through the old rack, with the normal quantity (300 cubic feet per second) running and the canal up to high-water mark, would average 1.5 feet per second if the rack had been so situated that each part of it supplied a proportional part of the water. This would have been ample for the present amount of water used. In actual practice not more than three-quarters of

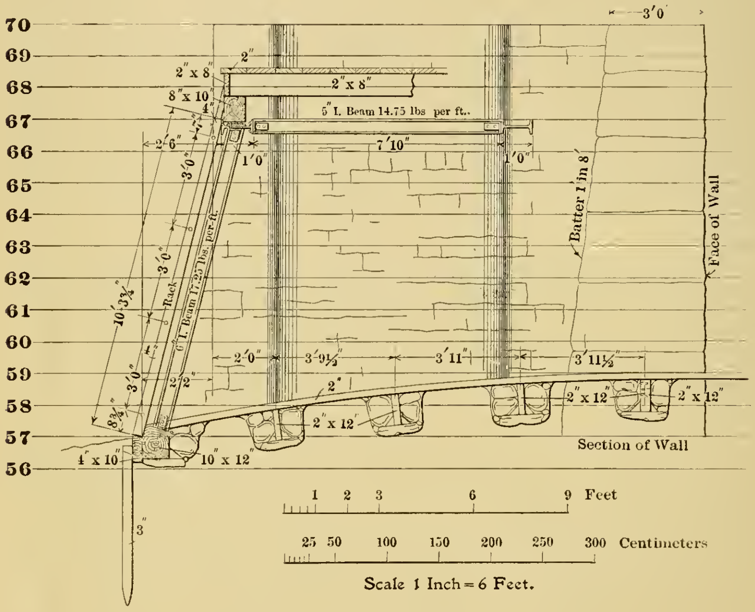


FIG. 3.

(For Figs. 1 and 2, see inset.)

the rack was in service, so that the average velocity was more than 2 feet per second.

After passing through the rack the water ran, for about 40 feet, through a section of the old feeder 27.5 feet wide and 6 feet high, containing five lines of posts, more or less in line, to support the wooden roof and the two or three feet of dirt above it. This portion of the feeder formed the head of a much older one which supplied the breast wheels of a half-century ago. Turning a right angle, the water ran for 150 feet through a channel of the same general form as the one of 40 feet already mentioned. Here the section was 20 feet wide and 6 feet high, with three lines of posts

to support the roof and the 4 to 5 feet of dirt on it; another right angle and distance of 20 feet brought the water through a section 32 feet wide and 6 feet high to a small open forebay, from which the water was drawn through a second set of racks, iron in this case, into the short wrought iron feeders which led directly to the wheels. The water, therefore, in getting from the canal to the wheels had, with various conditions of velocity and rest, to pass through two racks, turn two right angles and force its way by the lines of posts, which at the corners were oblique to the path of the water.

In addition to these obstructions, the water was constantly under a pressure of from one to two feet in going from one rack to another, so that the cross timbers supporting the roof formed a continuous line of obstructions to the flow.

The loss of head in getting from the canal to the wheels, due to this tortuous course, under the very best conditions obtainable, when the canal was free from leaves, ice and snow, was as follows:

	Loss of Head in Feet.	Area of Cross-section of Feeder in Square Feet. Approximate.	Average Velocity of Water, with 300 Cubic Feet per Second Passing.
From the canal through the first rack....	0.09	150	2.00
From behind the first rack down to the beginning of the second right angle......	0.76	{ 134.5 115.2	2.23 2.60
From beginning of second right angle through second rack....................	0.14	203.7	1.47
From in front of second rack to point just above the wheels or penstock gauge, so called	0.32	120.5	2.49
Total loss from canal to penstock gauges	1.31		

These average velocities are obtained by dividing the quantity (300 cubic feet per second) by the area at the point observed. They are somewhat misleading, because if the velocities had not been considerably higher at some parts of each section the total loss of head would not have amounted to 1.31 feet. The head required to generate the highest velocity in the table (2.6 feet per second) is but 0.105 feet, and the friction heads would be low, with these velocities, if there were no obstructions. I have given them simply to show the effect of obstructions in consuming head. It is evident that the continued changes in velocity, the abrupt turns and constant obstructions are of more importance than the mere velocity of the water. By remedying these unfavorable conditions the losses of head were reduced to almost nothing, and this feeder was made to serve its purpose well without being enlarged, except by raising the roof.

In addition to a need of more power in the mill and the saving which would result from stopping the steam engine, there were other reasons for putting in a new rack at this time. The water had undermined the sill of the old rack at one end, and there were several bad breaks in it which had been patched, thereby increasing the obstructions to the flow of the water. The current towards the rack in winter was sufficient to draw the floating ice and snow and plaster the upper part of the rack, still further diminishing the area through which the water went and making it extremely difficult to keep the rack clean. The $1\frac{1}{2}$-inch spaces between the slats were so large that small blocks of wood, sticks, etc., went through with the water, making it necessary to have an iron rack near the wheels, which further impeded the flow of water. The position of the old rack, the top being above water, allowed scum and grease floating in the canal to be drawn into the feeder, making it necessary to further screen the water before it could be used for washing cloth. The rack, being vertical, was very difficult to rake unless the canal was drawn off.

The demands on a good rack, which were certainly not fulfilled by this old wooden one, require an area large enough to let the water through with a uniformly low velocity; spaces between the slats large enough to allow the water to go through readily, but small enough to keep out anything liable to injure the wheels; a frame and slats strong enough to resist the total pressure of the water when the rack is plastered with ice for the full depth and the water drawn out behind it, which might happen when anchor ice is running; the top of the rack to be so far below the surface of the water that the area cannot be reduced by the ordinary accumulation of ice and snow; and a surface easy to keep clean. The last requirement is an important one, as the area of a rack can be reduced to almost nothing during certain seasons of the year by leaves and *débris* if it cannot be cleaned except by getting down into the bottom when the canal is drawn off.

In order to meet these requirements it was found best to replace the wooden rack with an iron one, and the writer was asked to make, to the Holyoke Machine Company, who built the rack, whatever suggestions were necessary to make it suitable for its purpose, and to design and build the foundations necessary to set the rack in place. The improvement of the feeder had been suggested previously to the Middlesex Company, and it was decided by the treasurer of this company to allow the engineer, in connection with the other work, to do whatever seemed necessary and wise to improve the feeder, in order that the water might be

brought to the wheels with the least possible loss of head consistent with economy. The use of a hoisting engine and derrick, which were necessary to build the piers for the rack, made it possible to do the work about the penstocks more economically at this time. The only requirement on the part of the company was that nothing should be done to interfere with the running of the mills during the week, from Monday morning to Saturday noon. This required that the work be done from Saturday night to Monday morning, when the canals are drawn off, and everything be left secure when the water was let on. The inside rack, already mentioned, was left in until the work was done, to protect the wheels from floating bits of wood. Work was begun on the last Sunday but one of August, 1899, and finished before cold weather came on.

The main frame of the new rack, Figs. 2 and 3, is composed of two 12-inch steel I beams, weighing 31.5 pounds per foot, placed 8 feet 10 inches apart on centers, set with the webs flat and the ends resting on pockets built in the masonry walls forming the head of the feeder. The one against which the rack irons are laid is 51 feet 4 inches long. Both of these I beams are set with the top of each flange at grade 67 on the scale of heights used, or about one foot below the ordinary running mark of the canal.

The span of 50 feet of the longer 12-inch beam is divided into three parts, of 16 feet 8 inches each, by two 6-inch steel I beams weighing 17.25 pounds per foot, the upper ends of which are fastened to the web of the 12-inch beam by angle irons; the lower ends, by means of angle irons, are lag-screwed to the main sill supporting the entire rack, and not bolted, as the section (Fig. 3) shows it. The other 12-inch beam, also of steel, weighing 31.5 pounds per foot, is 29 feet 6 inches long, the span being two feet less than this, or the full width of the feeder (Fig. 2). The span of 27 feet 6 inches is divided into two, of 13 feet 8 inches each, by a Georgia pine pier, sharpened back and front, so as to offer as little obstruction to the water as possible. Two 5-inch I beams, Fig. 3, weighing 14.75 pounds per foot, are placed between the two 12-inch beams at a distance of 5 feet 5 inches from each side of the feeder and in line with the two 6-inch beams mentioned before. They are level with the 12-inch beams, or a foot below the running mark, and serve to stiffen the rack.

The rack proper is 50 feet long and 10 feet high measured vertically, and has a clear area for the water of about 389 square feet. It is composed of panels of 4 x $\frac{1}{4}$-inch flat wrought iron bars 10 feet $3\frac{3}{4}$ inches long. They are held together by four $\frac{3}{4}$-inch bolts about 2 feet 6 inches long, making a panel of that width, with

$\frac{7}{8}$-inch washers to space the bars. These bolts are not set in the middle of the 4-inch bars, but back $2\frac{1}{2}$ inches from the front edge for convenience in raking the rack. These bolts divide the rack into three sections of 3 feet each, the top bolts being 7 inches from the end of the rack and the bottom ones $8\frac{3}{4}$ inches from the sill. These panels rest on the sill of the rack, which will be described later, and lean against the outer flange of the 12-inch I beam, each panel being hooked to the I beam to prevent the rack from being pushed out into the canal. The rack has a batter of 2 feet 6 inches in the 10 feet $3\frac{3}{4}$ inches, which slope makes it possible to rake the panels from the bottom up. The washers between the rack irons, which form the only obstruction to raking, are set back $2\frac{1}{2}$ inches from the front, as mentioned before, and, being rounded, they allow the teeth of the rake to pass between the rack irons without catching. Each panel of the rack was painted with black coal tar paint before being set in place.

The walls which support the ends of the two 12-inch beams carrying the rack form the head of the feeder. They are built upon the ends of a wooden floor for a distance of 16 feet from the sill supporting the racks back into the feeder, and form an opening which is ample to carry the water from behind the racks into the feeder proper without requiring any new loss of head in generating an increased velocity. The form of the opening behind the racks was such that each foot of rack, even to the extreme ends, would furnish its proportional amount of water.

The floor mentioned, Fig. 3, was laid lengthwise with the line of the feeder, over sills made up of 2-inch spruce plank 12 inches wide, to the bottom of which were spiked three-cornered cleats of spruce. These sills were laid in trenches dug just wide enough to get them in and the cleats covered with stone, and in some cases, where the material was wet, with concrete. These sills were laid at such a grade as would just allow the 2-inch spruce planking, planed on the upper side, to be bent, from the sill on which the rack rested, over the 12-inch sills to the grade required at the end of the 16-foot section. The sill to which the planking was spiked was composed of a 10 x 12-inch Georgia pine timber, the top of which was beveled to receive the two 6-inch beams forming the framework of the rack. To the back of this timber was nailed a cleat which was covered with concrete and stones, the trench being dug wide enough to allow stones a foot wide to be laid upon the cleat.

Spiked to this 10 x 12-inch timber, and in front of it, was a 4 x 10-inch Georgia pine timber with its top 4 inches below the top of the main sill, fashioned to receive the rack irons. The toe piling,

shown on the section, was composed of 3-inch tongued and grooved spruce plank, driven as far as possible by hand to depths from 2 to 4 feet below the top grade, as shown. This sheet piling was cut off a few inches below the top of the sill to provide for a possible flooring of the canal outside of the rack.

With the draft through the rack so light, on account of the increased area of the new rack, there may be some depositing of material on the bottom at the end of the floor, on account of its being nearly two feet lower than the general level of the bottom; but if provision is made for using nearly double the present quantity of water no such deposit will occur, and the area at this low level offsets that lost by burying the top of the rack under water.

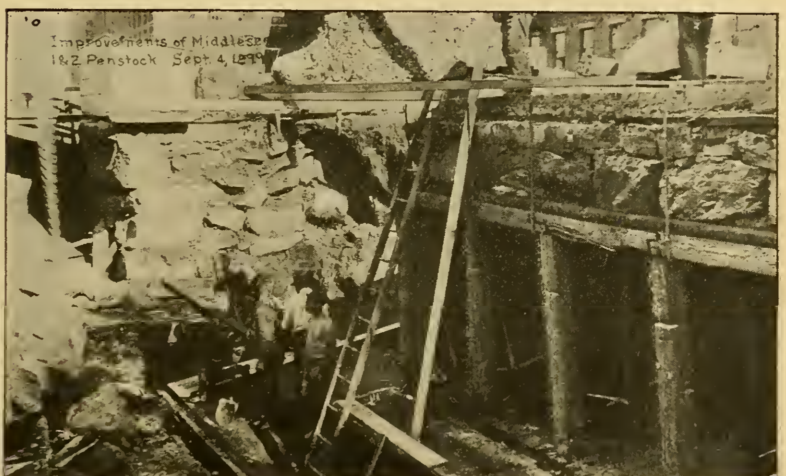


FIG. 4.

The new sill, besides being two feet lower, was located some few feet in front of the old one, and the two piers supporting the ends of the I beams were entirely outside the old feeder. These conditions allowed the new sills and a part of the flooring and walls to be put in without disturbing the old feeder. Fig. 4 shows the new sill in front of the old feeder and the new floor being laid.

The front of the pier is laid to the same batter as the rack irons when in place. The two piers at the head of the feeder, and a part of the feeder wall, were built, before the old feeder was taken out of the way, with a derrick, which was on the old feeder and placed so as to reach either pier at will. This made it possible to fill in behind both piers and prevent any washing of the bank here during the week when the mills were running.

While the two walls at the head of the feeder, and the sills and floor were being built about 2500 yards of material had been taken off the top of the feeder around to the mill wall, the last foot in depth being removed after the canals had been drawn off the Saturday night before Labor Day. During the next two days the roof timbers and planking forming the top of the old feeder were jacked up and lifted about three feet to a point above the high-water mark in the canal, and the blocking securely fastened so that it would not float away during the week. The walls were built up to meet the ends of the timbers supporting the roof, and a new line of 8 x 4-inch spruce posts was put in on the middle line of the feeder and sheathed on both sides with 1-inch boards, smooth on the water

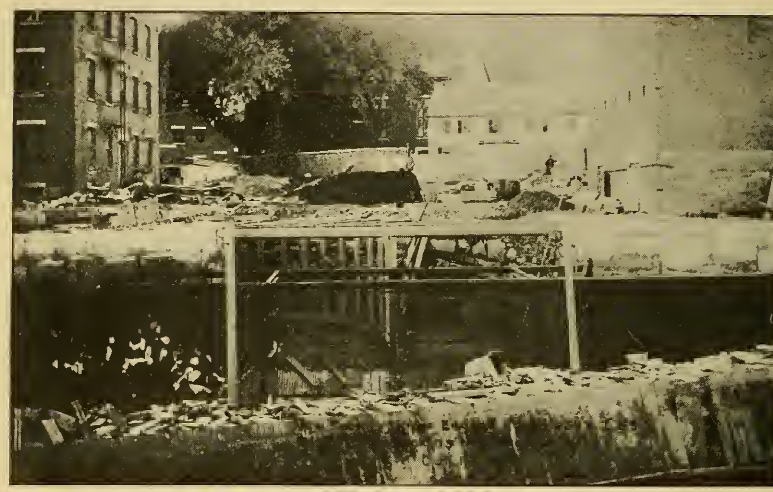


FIG. 5.

side, making two continuous partitions from a point 12 feet back of the new rack to the end of the section 150 feet long. The walls were rebuilt, and the corners rounded off with a rubble masonry wall pointed up as smoothly as possible.

Fig. 5 shows well the rack in place and the new central line of posts supporting the roof.

As the old yellow pine cross timbers supporting the roof were sound, and as they can be renewed readily, they were reset; the planking was patched up where necessary, and about one foot of earth was put back over the roof and graded off. There is left above the water an air space of about 6 inches and a foot of dirt, which during the past winter has been sufficient to keep the water in the feeder from freezing.

At the lower end of the feeder, at the second right angle, the masonry wall was built around to the mill only on one side; on the other side the curve was made by a wooden sheathed wall. The situation of the wheels was such that it became necessary to put in what might be called a curved arrow-head of wooden sheathing in order to bring the water to the wheels by an easy turn without changing the velocity. This simply required taking out all posts and putting in new ones on the line of the proposed sheathing and bending the 1-inch boards to the posts as laid out on the curve. The posts, to which the sheathing was nailed, carry the floor timbers as rearranged. The sheathing was not carried further down than a point within 3 feet of the floor, in order that there might be an opening from one feeder to the other in case one wheel only was running and it was necessary to use both feeders to supply it.

During the rebuilding of this feeder it was found that an old leak near the outside lower corner of the feeder had increased materially, due to the greater head on the leak caused by the improvements. A row of 2-inch tongued-and-grooved sheet piling 12 feet long was placed in the middle of a trench 3 feet wide, at a distance of 6.5 feet from the line of the old feeder down to a point below the bottom of the feeder, the top being well above high-water mark; and the trench was filled in on both sides of the piling with the best puddling material available on the work. This stopped the leak entirely, and it affords a complete protection to the basements of the mills, which are about 8 feet below the height of the water in the bank back of this sheet piling.

The bottom of the feeder was not changed, excepting the floor put in at the head of the feeder and already described. The bottom is composed of loose gravel and stone, with the ledge appearing in several places. This was simply cleaned up and left as smooth as scraping could make it. The gain due to diminishing the friction by the removal of the posts and the rounding of the corners was so great that it did not seem necessary to floor the feeder at present. It may be wise at some future time, when the draft through the feeder becomes greater, to lay a floor the entire length.

The difficulties attending work of this character are principally due to the short time possible for the completion of each section of the work.

The work would probably not have been undertaken by the Middlesex Company if there had been any stopping of their work during the regular week of fifty-eight hours, from Monday morning to Saturday noon. From the time the water was drawn off on Saturday night until Monday morning at six o'clock, the work was

so carried out that everything was in readiness to leave when the water was turned on. It required the attention of an engineer on the work continuously, to see that the work was carried on as expeditiously as possible.

Outside of these limitations of time, there were no unusual difficulties except the necessity of handling large quantities of water by pumps until the canal was entirely drained off. The material in the bottom was shoveled into dirt boxes and hoisted out by the derrick, deposited in piles and removed during the week. The laying of the sills and floor and other woodwork was done by carpenters furnished by the Middlesex Company; and all other work, including stone cutting, by a contractor, who furnished men and tools for a percentage of the cost of labor and materials used.

The masonry work was all granite rubble, laid in American Hoffman cement, excepting the piers at the head, which were cut from granite blocks to dimension by a stone cutter in the yard; laid as carefully as possible to line and grade, and pointed off smoothly on the inside or water side.

This work was completed during the Sundays of August, September, October and November, 1899. The first Monday of September being a mill holiday made it possible to have two days in succession, and some of the more difficult work of lifting the roof and getting in the sills was done then. Some of the material, down to the water, could be stripped off during the ordinary working days, and, by building certain sections of the masonry up above water line, the rest could be finished during the day or night. This, however, was a small part of the whole, most of the work being done Saturday night and Sunday. It was necessarily expensive work, as all labor was paid for at the rate of time and one-half for night and Sunday work, and it is not possible to get a good class of labor for work of this character. The total cost of all the work, including engineering and contractors' percentage, was about $5000.

The following table shows the height of water at different points, from the Lower Pawtucket Canal, through the feeder, to just above the wheels, before and since the improvements were made:

	July 22, 1898.	January 23, 1900.
Lower Pawtucket Canal....................	68.12	68.10
Just inside rack at head of feeder..........	68.03	68.02
Beginning of second right angle...........	67.27	67.98
Above location of old iron rack............	67.13	68.03
Just above wheels (penstock gauges)......	66.805	67.95
Quantity passing, cubic feet per second....	301.9	280.3

With the water in the canal at about the same height as before the improvements were made, the total effective head on the wheels (now 20.16 feet) is 1.16 feet (or 6 per cent.) greater than it was before, the water being but 0.15 foot lower at the wheels than in the canal after passing through the racks and feeder, instead of 1.31 feet, as it was formerly. This increased head makes it possible to draw about 3 per cent. more water through the same wheels than before, which amount of water is available as power with the total fall as improved. The gain is about 50 horse power; worth to the mill probably $1500 a year, in addition to the saving, in labor, of clearing the racks in winter. The quantity running on the 23d of January, 1900, was not quite as large as that on July 22, 1898.

Fig. 6.

Hence the foregoing table, which shows the losses of head on those dates, is somewhat in favor of the conditions as improved.

A comparison, under ordinary working conditions in the mill, on two days when the quantity drawn through the feeder was the same shows the following losses of head from the Lower Pawtucket Canal to the penstock gauges:

	December 9, 1898.	April 5, 1900.
Lower Pawtucket Canal....................	68.10	68.10
Just above wheels (penstock gauges).......	67.02	67.93
Loss of head from canal to just above wheels, in feet....................................	1.08	0.17
Saving in loss of head.....................	....	0.91
Quantity drawn through feeder in cubic feet per second..............................	282.8	282.1

There was no loss through the feeder from "just inside rack at head of feeder" to gauge "above location of old iron rack" on January 23, 1900, as against 0.9 foot on July 22, 1898. The latter loss, with 280.3 cubic feet per second, or the same quantity running as on the first date, would have been about 0.77 foot. This difference of 0.77 foot shows the loss through the feeder due to the posts and the sharp turns.

In addition to the actual gain in effective head, the freedom from trouble by ice and snow is a very important help. With the top of the new rack under water there is little chance of its being plastered up with ice and snow, which formerly necessitated the shutting down of the mills until the racks could be cleaned, and required a number of men for several hours during the winter season. Only two shut-downs were necessary during the past winter. This is a very noticeable improvement, because, although it was a mild winter, the amount of anchor ice was unusually large.

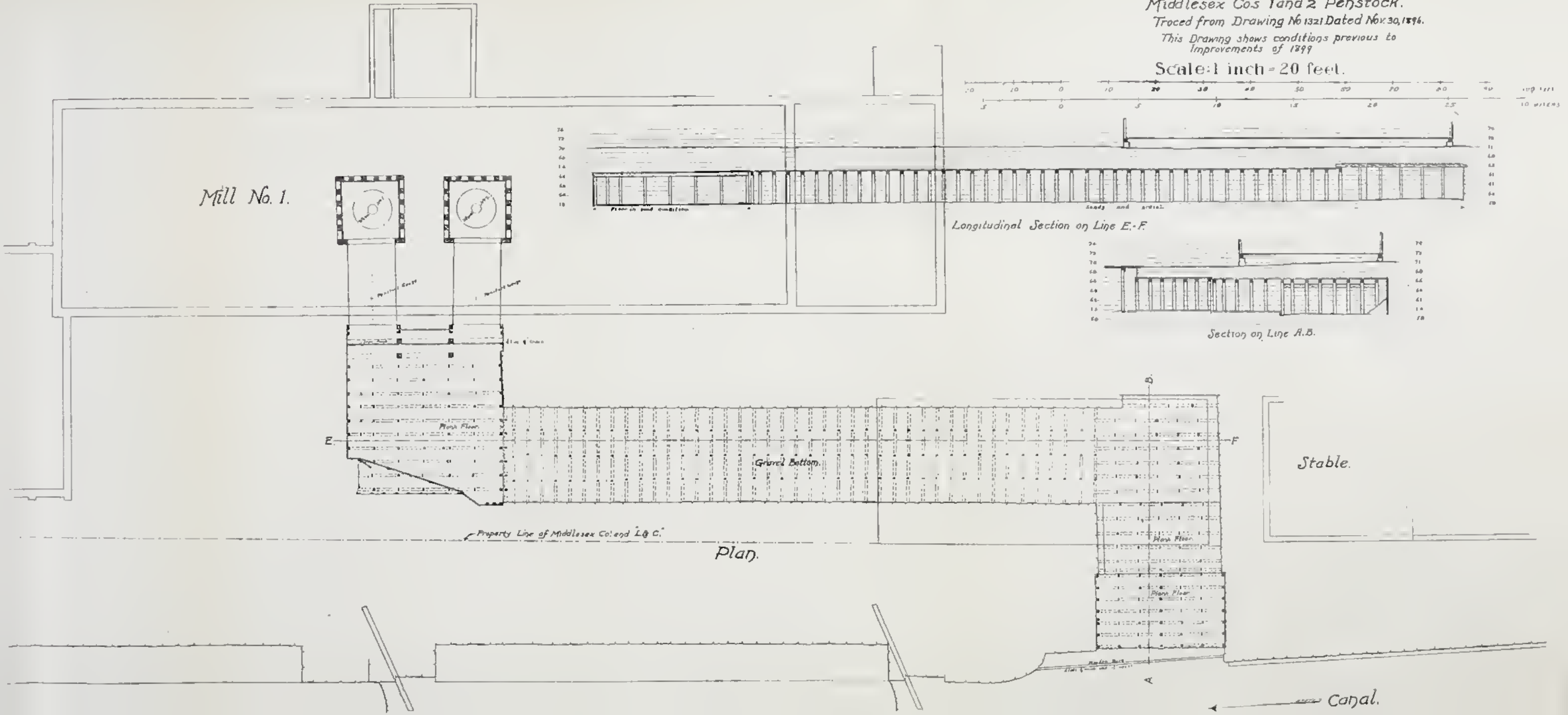
Fig. 6 shows the pile of *débris* which has been taken from the rack up onto the platform above it.

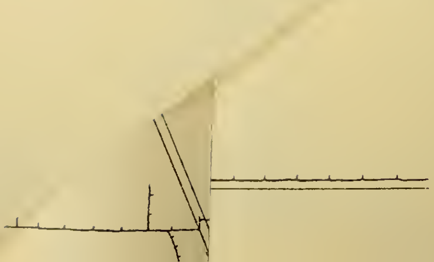
It is not intended to create the impression that this work was of any considerable magnitude. It is simply an example of the many interesting problems which come up in a place like Lowell, Mass., where a hydraulic engineer is asked to improve the water power in the short time available out of mill hours; and where the work is appreciated not solely for actually increasing the water power of the mill, but for simplifying the conditions under which the water power can be controlled.

In the design and execution of this work I have had the assistance of Mr. George W. Mansur, of Lowell, Mass., and I am deeply indebted to him for his interest and energy in obtaining the results required.

FIG 1.
Scale Drawing of
Middlesex Co's 1 and 2 Penstock.
Traced from Drawing No 1321 Dated Nov. 30, 1896.
This Drawing shows conditions previous to Improvements of 1899

Scale: 1 inch = 20 feet.





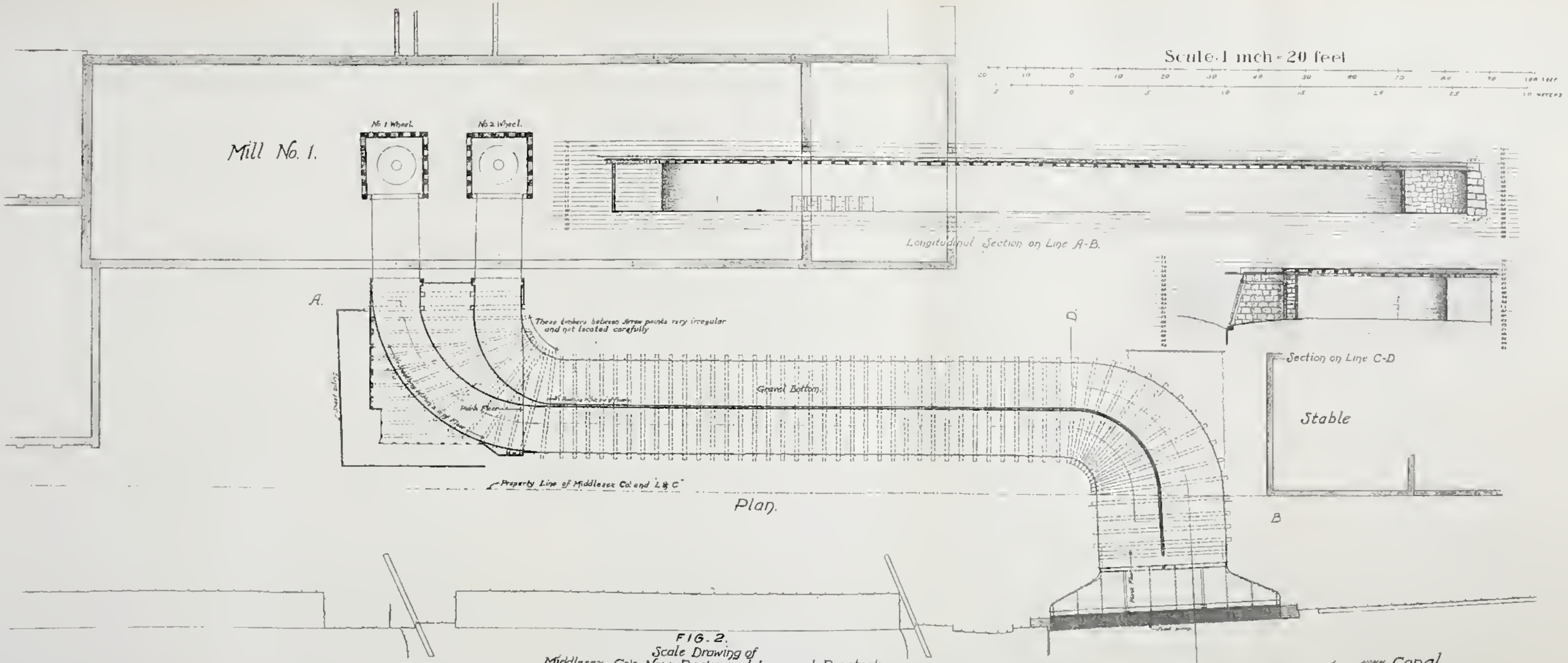
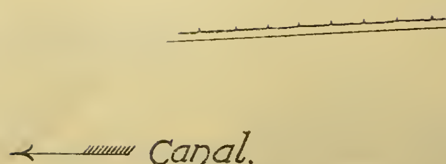


FIG. 2.
Scale Drawing of
Middlesex Co's. New Racks and Improved Penstock
for No. 1 and 2 Wheels.
Oct. 27, 1899


Canal.

THE INIDIKIL SYSTEM.

A Decimal System of Weights and Measures for the English-Speaking People.

By A. Lincoln Hyde, Ph.B., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, June 12, 1900.*]

"Progress is the law of life," said Robert Browning, and I believe we all agree that we live to progress. Man was given senses to appreciate nature, and a brain to adapt the products and forces of nature to his convenience and comfort. The inventive mind is ever at work in an endeavor to discover a new force, or a new method of applying a known force. The tendency is ever toward simplicity, ever toward economy. The effort of the mechanical engineer is to reduce the number of working parts of a machine, to reduce the friction, to obtain the best possible results with the least expenditure of energy.

In the June number of the *Century*, Mr. Nikola Tesla has a paper entitled "The Problem of Increasing Human Energy." The problem with which we have to deal to-night is the problem of saving mental energy. A system of coinage is a convenience for the measure of values, and a system of weights and measures is a convenience for the measure of materials. No fault is found with the system of coinage in use in the United States, but the prevailing system of weights and measures is far from being the most convenient that could be used. A new system is suggested. It is founded on the common unit of the present system. The number of working parts has been reduced to reasonable limits and the parts themselves have been made as simple as possible.

As far as its application to abstract numbers is concerned, the Arabic or decimal system of notation has been accepted as best by all nations. To the French people belongs the credit of first having applied it to a standard of weights and measures. Although the suggestion of such action was made in the time of Philippe le Bel, who reigned from 1285 to 1314, the scheme did not take definite form until 1790, when proposals were made by the French Government to the British for a meeting of an equal number of members from the Academy of Sciences and the Royal Society of London, with a view to making a new system of measures. The proposals were not favorably received by the British, and the French, impatient to effect the much-needed reform, appointed the commission which evolved the metric system. This system received legal sanc-

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tion by the French Government November 2, 1801, and has been the only system in general use in France since 1840.

It might be said that if the overtures made by the French in 1790 had met the favorable consideration of the British, the metric system would have been the universal and only system in use to-day. Little is gained by dwelling on what might have been. It is far better for us to adapt ourselves to the conditions as we find them, and to date our efforts in the line of progress from the present.

The metric system was the result of careful deliberation and logical reasoning. Its practical use has developed two points. The number of terms for units adopted was too large, and the terms themselves are too cumbersome for general practice. About one-half the number of terms adopted are in common use, and it has been found necessary to abbreviate these and to designate them by their initial letters.

The metric system was at first met with the opposition of prejudice and lack of appreciation, and was nearly a half-century in establishing itself in the country which created it. Its value was recognized at once, however, by scientists, and its use was legalized by the several greater nations. Germany very gracefully adopted it immediately after the close of the Franco-Prussian War, and Russia accepted it about a year ago. It is the standard of Italy, Spain and Mexico, as well as that of almost all of the smaller countries. It is stated as true that the metric system is now used by the majority of the people of the globe, but, notwithstand this fact, if it, indeed, be a fact, the two great manufacturing nations of the world, Great Britain and the United States, have not yet seen fit to adopt it.

The reason for suggesting a decimal system of weights and measures for the English-speaking nations is due to the fact that the numerous and strenuous efforts to have the use of the metric system made compulsory in Great Britain and the United States have ignominiously failed. The development of industries in these countries has been so great and along such lines that they are growing away from rather than towards the use of the metric system.

The most just opposition to the introduction of the metric system into the United States to-day is met in the machine shop. The amount of capital invested in machinery and in the manufacture of machinery is so enormous as practically to prohibit the adoption of this admirable system.

It does not necessarily follow that because we cannot accept the metric system, we must bend forever beneath the burden of our present brain-fagging and error-producing systems.

In these days of advancement it is an unnatural retardation of progress to cling tenaciously to systems of linear and surface measure with arbitrary modes of division; to cling to three systems of measure of capacity when one will suffice; to cling to three systems of weight. An improvement on the present practice must be made sooner or later.

The surveyor, for his convenience, has divided the foot into tenths, hundredths and thousandths, but for the machine shop and the rolling mill the foot is no better than the meter as a basis of a decimal system.

The inch, however, is a unit common to all, and is the logical basis for a decimal system of weights and measures. The fractions of an inch in general use are exact decimals of an inch. The micrometer scales in the machine shop and in the physical laboratory read to tenths, hundredths and thousandths of an inch. Nominally, the yard is the standard of English measure, and the foot and the inch are subdivisions of the yard. In reality the inch is the common unit of English measure, and should be adopted as the standard. The inch is already divided decimally. Let us multiply it by ten for a new unit, and let us multiply this new unit by ten for another, and so on, until a sufficient number of units has been obtained to meet our needs. The time is ripe for the banishment of both the foot and the yard.

Let us build a decimal system of weights and measures on the inch as a basis.

We have stated that the only just opposition to the metric system has come from the machine shop. In building a decimal system on the inch we cannot be met with just opposition from the machine shop; we cannot be met with just opposition from the surveyor; we cannot be met with just opposition from any source.

In selecting unit terms for the proposed system let us profit by the experience of the metric system. Four terms each for units of length, area, capacity and weight will be sufficient for all ordinary purposes. Let us make our terms so simple that they will require no abbreviation. Let us agree that the plurals of the terms shall be the same as the singulars.

In introducing new words into the English language it is customary to borrow from some foreign language—living or dead. Let us be bold enough to coin the terms necessary for our use from the raw material of the alphabet. Two letters, one vowel and one consonant, are sufficient to form a pronounceable word, and one that will require no abbreviation. Let us so form our terms.

Starting with linear measure, we know that the word inch is usually abbreviated to *in* by those who have occasion frequently to use the word. Let us accept this as satisfactory for one term, and for the other three terms let us combine the same vowel *i* with three such consonants as will prevent any one term being mistaken for any other term, either in writing or speaking. The three consonants *d, k* and *l* will meet these requirements, and our terms will be *in, id, ik* and *il.*

For the units of surface measure let us simply abbreviate the word square to *sq,* and add respectively the terms selected for linear measure. Our terms for units of measure of area will be *sqin, sqid, sqik* and *sqil.*

In selecting terms for designating units of capacity let us agree at the outset that one set of terms for units of cubical contents of all kinds will suffice. Let us abbreviate the word cubic to *cub,* and add respectively the terms for linear measure as before. Our terms for units of measure of capacity will be *cubin, cubid, cubik* and *cubil.*

In a similar manner let us select terms for units of weight. We can do no better than follow the example of the metric system in selecting the basis for our system of weights. Let us use the weight of one cubic inch or *cubin* of distilled water at its greatest density, 4 degrees Centigrade, the barometer standing at 30 inches or 3 *id.* Let us designate the units, tens, hundreds and thousands of this weight by simple terms coined as before from two letters. Let us use the first letter of the alphabet for the vowel in connection with the same consonants used in our terms for linear measure, and in the same order. Our terms for units of weights will be *an, ad, ak* and *al.*

Our tables of value are simple, and are as follows:

Measure of Length.

In	1 in	1 inch
Id	10 in	10 inches
Ik	100 in	100 inches
Il	1,000 in	1,000 inches

Measure of Surface.

Sqin	1 sqin	1 square inch
Sqid	100 sqin	100 square inches
Sqik	10,000 sqin	10,000 square inches
Sqil	1,000,000 sqin	1,000,000 square inches

Measure of Capacity.

Cubin	1 cubin	1 cubic inch
Cubid	1,000 cubin	1,000 cubic inches
Cubik	1,000,000 cubin	1,000,000 cubic inches
Cubil	1,000,000,000 cubin	1,000,000,000 cubic inches

Weight.

An	1 an	weight of	1 cubic inch	of water
Ad	10 an	weight of	10 cubic inches	of water
Ak	100 an	weight of	100 cubic inches	of water
Al	1,000 an	weight of	1,000 cubic inches	of water

In order to distinguish the proposed decimal system of weights and measures from the prevailing systems, let us give it a name. If we combine the terms selected for units of linear measure in regular order we shall have the word *in-id-ik-il.* This is certainly euphonious and easily remembered. Further, it is a master key to the entire system, the substitution of the vowel *a* for the vowel *i* giving the key to the system of weights.

Having decided upon our units, it is a simple matter to make a table of equivalents for use during the transition period. To reduce from the common or English system to the *inidikil system* it is only necessary to reduce to inches, square inches or cubic inches, as the case may require, and to put the decimal point in the proper place. The reduction of weights from one system to the other is also very easily effected.

Tables showing the precise equivalents of the common units of the three systems, English, metric and *inidikil,* each in terms of the other two are given on pages 43, 44 and 45, and a table of precise equivalents of the common units of the *inidikil* and metric systems, each in terms of the other, is given on page 46.

In the table of precise equivalents now in general use by those who have occasion to translate from the English to the metric system and *vice versa,*—comprising the tables on pages 43 to 45 with the middle column omitted,—there are thirty-nine factors, while in the table on page 46, which would be used if the proposed *inidikil system* were adopted, *there are but six.*

The advantages claimed for the *inidikil system* are the advantages which obtain in the use of any decimal system; the ease with which the change from the English system can be made; the close relationship to the metric system; the simplicity of the system itself, and the economy resulting from its use.

The advantages of a decimal system are too well known to require demonstration. A mental comparison of the monetary systems of Great Britain and the United States is sufficient to convince the average mind.

The ease with which the change can be made must readily be comprehended. For the present it simply means the adoption of one new unit-term equal to ten inches. Time can be taken to perfect the suggested system and to make provision for the change. The inch is already establishing itself as the only unit of linear measure in the machine shop. In the rolling mill the widths and thicknesses of all plates, the sizes and thicknesses of all shapes, are given in inches. In the boiler shop all dimensions of plates are given in inches. All dimensions of plate glass are given in inches. The dimensions of pictures in our art galleries are given in inches. The widths of cloth, wall paper, carpeting, draperies, etc., are given in inches. Then why not all dimensions of all materials in inches or in decimal multiplications or decimal divisions of the inch?

The plasterer measures his surfaces with a foot rule, computes his areas in square feet and faithfully divides by nine to reduce to square yards. The stone mason also measures his work with a foot rule, computes his contents in cubic feet and divides by twenty-seven to reduce to cubic yards. And this, day in and day out, year in and year out, on every job that is figured. Surely, some men must love work for work's sake, since nothing is accomplished by these long-continued senseless operations. But it is custom! Energy always has been wasted in this way; it has come to be an established custom to waste energy in this way, therefore we must always waste energy in this way!

We have made some progress. When we think of the list of terms, including the barleycorn, inch, digit, palm, hand, link, span, foot, cubit, yard, ell, fathom, rod or pole, chain, furlong, cable's length, statute mile, nautical mile, knot, league, square inch, square foot, square yard, square of one hundred square feet, square rod or perch, rood, acre, quarter-section, square mile or section, township, cubic inch, cubic foot, cubic yard, perch of sixteen and one-half cubic feet, perch of twenty-two cubic feet, perch of twenty-four and three-quarters cubic feet, ton of one hundred cubic feet, cord, fluid minim, drachm and ounce, liquid gill, pint, quart and gallon, dry quart, peck and bushel, grain, scruple, pennyweight, drachm, ounce (Troy), ounce (avoirdupois), pound (Troy), pound (avoirdupois), stone, quarter, quintal, hundredweight, net ton and gross or long ton, when we think of the sea of radices: 2, 3, 4. 5.5,

6, 7.92, 8, 9, 12, 14, 16, 16.5, 20, 22, 24, 24.75, 27, 28, 36, 40, 66, 80, 100, 112, 120, 128, 144, 160, 231, 437.5, 480, 1728, 2150.42, etc.—when we think of all this, we cannot help feeling that we have made some progress. But we have not made sufficient progress. Even now our system of weights and measures is "an unweeded garden that grows to seed; things rank and gross in nature possess it merely." A system of twelve simple terms with a single radix, ten, is sufficient for the convenient handling of the general business of the English-speaking nations.

Simplicity is claimed for the proposed *inidikil system* and a comparison in parallel of the three systems, English, metric and *inidikil*, will bear out this claim.

English.	*Metric.*	*Inidikil.*
inch	millimetre	in
foot	centimetre	id
yard	metre	il
mile	kilometre	sqin
square inch	centare	sqid
square foot	are	sqil
square yard	hectare	cubin
square	cubic centimetre	cubid
acre	litre	cubik
cubic inch	cubic metre	an
cubic foot	gram	ad
perch	tonne	al
cubic yard	kilo	
cord		
minim		
drachm		
ounce		
gill		
pint		
quart		
gallon		
quart		
peck		
bushel		
grain		
scruple		
pennyweight		
drachm		
ounce (Troy)		
ounce (Av'd)		
pound (Troy)		
pound (Av'd)		
hundredweight		
ton (net)		
ton (gross or long)		

Economy is also claimed. To the person who does not use weights and measures the system signifies little or nothing, but to the man whose daily work is made up of arithmetical operations involving terms representing weights and measures it signifies much. Aside from the bookkeeper, who uses figures to represent dollars and cents, and who, in this respect, is well taken care of by a deci-

mal system, the structural draftsman, perhaps, uses the most figures in his work. Next in order come the architect, civil engineer and mechanical engineer.

To prove our claim of economy, let us again try the "deadly parallel." I give below one line of dimensions taken from the working drawing for an ordinary built-up column composed of two ten-inch channels laced, and in parallel the dimensions as they would appear if the *inidikil system* were in vogue.

English System.		*Inidikil System.*	
	0′ — 2″		0′.2
	0′ — 2½″		0′.25
	0′ — 3½″		0′.35
	0′ — 3½″		0′.35
	0′ — 2½″		0′.25
6 spa. @ 3¼″	1′ — 7½″	6 spa. @ 3″.25	1′.95
	0′ — 2¾″		0′.34
28 spa. @ 5⅞″	13′ — 8½″	28 spa. @ 5″.85	16′.38
3 spa. @ 4½″	1′ — 1½″	3 spa. @ 4″.5	1′.35
	0′ — 2¼″		0′.23
	0′ — 2¼″		0′.23
3 spa. @ 4½″	1′ — 1½″	3 spa. @ 4″.5	1′.35
28 spa. @ 5⅞″	13′ — 8½″	28 spa. @ 5″.85	16′.38
3 spa. @ 4³/₁₆″	1′ — 0⁹/₁₆″	3 spa. @ 4″.4	1′.32
	0′ — 2³/₁₆″		0′.22
	0′ — 2³/₁₆″		0′.25
3 spa. @ 4³/₁₆″	1′ — 0⁹/₁₆″	3 spa. @ 4″.25	1′.275
25 spa. @ 5⅞″	12′ — 2⅞″	25 spa. @ 5″.85	14′.625
15 spa. @ 4⅛″	5′ — 1⅞″	15 spa. @ 4″.15	6′.225
	0′ — 5⅛″		0′.475
	0′ — 1⅜″		0′.15
	53′ — 5½″		64′.15

By checking the multiplications indicated and the total length of the column by adding the minor dimensions, some idea of the time that would be saved by using the *inidikil system* will be gained. Remember that this is but one line of dimensions. On one twenty-four by thirty-six-inch sheet working drawing there are from thirty to fifty times as many figures as are here given, and the number of sheets to a job varies from five to one hundred.

It is known that about one-third the total time spent on a working drawing is given to the arithmetical calculations and to the putting down of figures or dimensions. It is also known that it takes about one-third as long to check a working plan as to make a complete working plan. It is believed that fifty per cent. of the time spent in making the arithmetical calculations and putting down the dimensions, and fifty per cent. of the checker's time, or twenty-five per cent. of the whole time spent on a working drawing, could be saved by the use of the *inidikil system.* Suppose a bridge company employs ten draftsmen at an average of $1000 each per year and the company could save ten per cent. or $1000

per year, would not this amount be worth saving? I am confident that a company in such a case could save from $1000 to $2500 by using the proposed decimal system. There are several companies employing regularly from thirty to fifty and some as high as a hundred draftsmen. For a company employing fifty draftsmen the saving would be in the neighborhood of $10,000, or the interest on an investment of $250,000. Surely such an amount must be worth saving! And this is in the drafting department alone; there would also be a saving in the engineering or estimating department, and in the shop. All manufacturers would be benefited, all engineers, all architects, all users of a system of weights and measures. In addition to the great financial saving, all draftsmen and checkers would be relieved of a great mental strain.

ENGLISH SYSTEM.

Table of Precise Equivalents in Terms of Inidikil and Metric Systems.

English.	Inidikil.	Metric.
1 inch	1.0000 in	2.5400 cm.
1 foot	1.2000 id	30.4800 cm.
1 yard	3.6000 id	0.9144 m.
1 mile	63.3600 il	1.6093 km.
1 sq. inch	1.0000 sqin	6.4516 sq. cm.
1 sq. foot	1.4400 sqid	0.0929 sq. m.
1 sq. yard	12.9600 sqid	0.8361 sq. m.
1 acre	6.2726 sqil	0.4047 hectar
1 cu. inch	1.0000 cubin	16.3900 cu. cm.
1 cu. foot	1.7280 cubid	0.0283 cu. m.
1 cu. yard	46.6560 cubid	0.7645 cu. m.
1 pint (liq.)	28.8750 cubin	0.4732 litres
1 quart (liq.)	57.7500 cubin	0.9463 litres
1 quart (dry)	67.2000 cubin	1.1010 litres
1 gallon	231.0000 cubin	3.7853 litres
1 peck	537.6000 cubin	8.8090 litres
1 bushel	2.1504 cubid	35.2360 litres
1 grain	0.00396 an	0.0648 gram
1 ounce (Av'd)	1.73010 an	28.3526 grams
1 ounce (Troy)	1.90100 an	31.1038 grams
1 pound (Av'd)	2.76820 ad	0.4536 kilo
1 ton (2,000 lbs.)	55.36400 al	0.9072 tonnes
1 ton (2,240 lbs.)	62.00770 al	1.0170 tonnes

METRIC SYSTEM.

TABLE OF PRECISE EQUIVALENTS IN TERMS OF INIDIKIL AND ENGLISH SYSTEMS.

METRIC.	INIDIKIL.	ENGLISH.
1 mm.	0.0394 in	0.0394 inch
1 cm.	0.3937 in	0.3937 inch
1 m.	3.9370 id	3.2809 feet
1 km.	39.3700 il	0.6214 miles
1 sq. cm.	0.1550 sqin	0.1550 sq. in.
1 sq. m.	15.5000 sqid	1.1960 sq. yds.
1 hectar	15.5000 sqil	2.4710 acres
1 cu. cm.	0.0610 cubin	0.0610 cu. in.
1 litre	61.0234 cubin	0.9081 q'rt (dry)
1 litre	61.0234 cubin	1.0567 q'rt (liq.)
1 cu. m.	61.0234 cubid	1.3078 cu. yds.
1 gram	0.0610 an	15.4306 grains
1 kilo	6.1022 ad	2.2046 pounds
1 tonne	61.0222 al	1.1020 tons (2000 lbs.)
1 tonne	61.0222 al	0.9842 tons (2240 lbs.)

INIDIKIL SYSTEM.

Table of Precise Equivalents in Terms of English and Metric Systems.

Inidikil.	English.	Metric.
1 in	1.0000 inch	2.5400 cm.
1 id	0.8333 foot	25.4000 cm.
1 ik	8.3333 feet	2.5400 m.
1 il	83.3333 feet	25.4000 m.
1 sqin	1.0000 sq. inch	6.4516 sq. cm.
1 sqid	0.6944 sq. foot	645.1600 sq. cm.
1 sqik	7.7160 sq. yards	6.4516 sq. m.
1 sqil	771.6044 sq. yards	645.1600 sq. m.
1 cubin	1.0000 cu. inch 0.5541 fluid oz.	16.3900 cu. cm.
1 cubid	0.5787 cu. foot 4.3290 gallons 0.4650 bushels	16.3900 litres
1 cubik	21.4324 cu. yards	16.3900 cu. m.
1 an	252.6983 grains 12.6347 scruples 10.5289 pwts. 4.2116 drachms 0.5265 oz. (Troy) 0.5776 oz. (Av'd)	16.3900 grams
1 ad	5.2644 oz. (Troy) 5.7759 oz. (Av'd)	163.9000 grams
1 ak	4.3870 lbs. (Troy) 3.6099 lbs. (Av'd)	1.6390 kilos
1 al	36.0991 lbs. (Av'd)	16.3900 kilos

INIDIKIL AND METRIC SYSTEMS.

Precise Equivalents.

Inidikil.	Metric.	Metric.	Inidikil.
1 in 1 id 1 il	2.5400 cm. 0.2540 m. 25.4000 m.	1 cm. 1 m. 1 km.	0.3937 in 3.9370 id 39.3700 il
1 sqin 1 sqid	6.4516 sq. cm. 0.0645 sq. m.	1 sq. cm. 1 sq. m.	0.1550 sqin 15.5000 sqid
1 cubin 1 cubid 1 cubik	16.3900 cu. cm. 16.3900 litres 16.3900 cu. m.	1 cu. cm. 1 litre 1 cu. m.	0.0610 cubin 0.0610 cubid 0.0610 cubik
1 an 1 ad 1 al	16.3900 grams 0.1639 kilo 16.3900 kilos	1 gram 1 kilo 1 tonne	0.0610 an 6.1022 ad 61.0222 al

A few illustrations will serve to show some of the values that would come into general use if the *inidikil system* were accepted. The equivalent and the value now in use are given for comparison.

DOMESTIC POSTAGE.

Matter.	Rate.	New.	Equivalent.	Old.
First Class Letters, etc.	2c.	2 an	1.16 oz.	1 oz.
Second Class Newspapers, Periodicals	1c.	7 an	4.04 oz.	4 oz.
Third Class Books, Circulars	1c.	4 an	2.31 oz.	2 oz.
Fourth Class Merchandise	1c.	2 an	1.16 oz.	1 oz.

ATMOSPHERIC PRESSURE.

New.	Equivalent.	Old.
40 *ad* per *sqin*	40.83 *ad* per *sqin*	14.75 lbs. per sq. inch.

STEAM PRESSURE.

New.	Equivalent.
0.15 *al* per *sqin*	5.4 lbs. per sq. inch
0.30 *al* per *sqin*	10.8 lbs. per sq. inch
1.00 *al* per *sqin*	36.1 lbs. per sq. inch
2.00 *al* per *sqin*	72.2 lbs. per sq. inch
3.00 *al* per *sqin*	108.3 lbs. per sq. inch
4.00 *al* per *sqin*	144.4 lbs. per sq. inch
5.00 *al* per *sqin*	180.5 lbs. per sq. inch
6.00 *al* per *sqin*	216.6 lbs. per sq. inch
7.00 *al* per *sqin*	252.7 lbs. per sq. inch
8.00 *al* per *sqin*	288.8 lbs. per sq. inch
9.00 *al* per *sqin*	324.9 lbs. per sq. inch
10.00 *al* per *sqin*	361.0 lbs. per sq. inch

ALLOWED PRESSURE ON MASONRY.

Kind.	New.	Equivalent.
Brickwork	2.80 *al* per *sqin* to 4.20 *al* per *sqin*	101.1 lbs. per sq. inch to 151.6 lbs. per sq. inch
Stonework	7.00 *al* per *sqin* to 8.30 *al* per *sqin*	252.7 lbs. per sq. inch to 299.6 lbs. per sq. inch

LOADS AND PRESSURES.

The following are loads or pressures expressed in *al* per *sqid* with equivalent values in pounds per square foot, and will suffice to cover wind pressures, snow loads and the usual dead and live loads in common use among engineers and architects:

Al per Sqid.	Pounds per Sq. Foot.	Al per Sqid.	Pounds per Sq. Foot.
0.10	5.2	2.00	104.0
0.20	10.4	3.00	156.0
0.30	15 6	4.00	208.0
0.40	20.8	5.00	260.0
0.50	26.0	6.00	312.0
0.60	31.2	7.00	364 0
0.80	41.6	8 00	416.0
1.00	52.0	10.00	520.0

WEIGHTS OF SUBSTANCES.

Substance.	Al per Cubid.	Pounds per Cubic Foot.
Aluminum	2.60	162.0
Brickwork	1.80	112.0
Carbon	3.40	211.0
Cement (Portland)	1.40	90.0
Cement (Natural)	0.90	56.0
Coal	0.90	58.0
Copper	8.90	555.0
Earth	1.50	95 0
Gold	19.34	1204.0
Granite	2.70	170 0
Iron (Cast)	7.20	450 0
Iron (Wrought)	7.70	480.0
Lead	11.36	709.0
Mercury	13.50	842.0
Oak (Live)	0.95	59.0
Pine (White)	0.40	25.0
Pine (Yellow)	0 70	45.0
Platinum	21.53	1343.0
Sandstone	2.40	151.0
Snow (freshly fallen)	0 20	12.0
Snow (wet compact)	0.80	50.0
Silver	10.50	655.0
Steel	7.85	490.0
Water	1.00	62.4

Note.—To reduce from pounds per cubic foot to *al* per *cubid,* multiply by 0.01603.

To reduce from *al* per *cubid* to pounds per cubic foot, multiply by 62.38.

The specific gravity of any substance is equal to its weight in *al* per *cubid.*

ALLOWED FIBER STRESSES FOR WOODEN BEAMS.

New.	Equivalent.
20 *al* per *sqin*	722 lbs. per sq. inch
25 *al* per *sqin*	953 lbs. per sq. inch
30 *al* per *sqin*	1083 lbs. per sq. inch
35 *al* per *sqin*	1264 lbs. per sq. inch
40 *al* per *sqin*	1444 lbs. per sq. inch
45 *al* per *sqin*	1625 lbs. per sq. inch

ALLOWED STRESSES ON RIVETS.

Shear.	
New.	Equivalent.
16 *al* per *sqin* to 32 *al* per *sqin*	5,780 lbs. per sq. inch to 11,550 lbs. per sq. inch

Bearing.	
New.	Equivalent.
32 *al* per *sqin* to 64 *al* per *sqin*	11,550 lbs. per sq. inch to 23,100 lbs. per sq. inch

EXTREME FIBER STRESSES ON PINS.

New.	Equivalent.
40 *al* per *sqin* to 70 *al* per *sqin*	14,440 lbs. per sq. inch to 25,270 lbs. per sq. inch

ULTIMATE STRENGTH PER SQIN OF STEEL.

Kind.		New Limit.	Precise Equiv.	Old Limit.
Rivet	min. max.	1,300 *al* 1,600 *al*	46,930 lbs. 57,760 lbs.	48,000 lbs. 58,000 lbs.
Soft	min. max.	1,400 *al* 1,700 *al*	50,540 lbs. 61,370 lbs.	52,000 lbs. 62,000 lbs.
Medium	min. max.	1,600 *al* 1,900 *al*	57,760 lbs. 68,590 lbs.	60,000 lbs. 70,000 lbs.

The weight of floors for railroad bridges, now assumed at 400 pounds per linear foot, would become 10 *al* per *id,* equal to 433 pounds per linear foot.

The equivalent uniform loads for Cooper's heaviest engine, which vary from about 9000 pounds to 4000 pounds per linear foot, would be assumed at from 200 *al* to 100 *al* per *id* or from 8666 pounds to 4333 pounds per linear foot.

For the inch-pound we would substitute the *in-al* and the equivalents would be:

1 inch-pound, 0.0277 in-al.
1 in-al, 36.1 inch-pounds.

For the foot-pound we would substitute the *id-al* and the equivalents would be:

1 foot-pound, 0.03324 id-al.
1 id-al, 30.084 foot pounds.

A horse power, now assumed at 33,000 foot-pounds, would equal 1.097 *id-al.* A new unit of work, 1000 *id-al,* equal to 30,084 foot-pounds, would undoubtedly be assumed.

The equivalent heat unit now in use is assumed at 772 foot-pounds and represents the amount of energy necessary to raise the temperature of one pound of water one degree, Fahrenheit. A new heat unit based on the Centigrade thermometer would be adopted and would equal 1668 *id-ad.* In other words a weight of 1668 *ad* falling through a space of one *id* would create the energy necessary to raise the temperature of one *ad* or ten *cubin* of water one degree Centigrade.

As already stated, the changes in linear, surface and ordinary cubic measure are very quickly comprehended. Two hundred *cubin,* fifty *cubin* and twenty-five *cubin* would soon come to be recognized as respective approximate equivalents of the liquid gallon, quart and pint. Likewise, two *cubid* as the approximate equivalent of a bushel and one *ad* as approximately one-third of a pound. It would probably be advisable to adopt one more term, *ar,* equal to one-thousandth part of one *an,* for the convenient designation of the weight of such drugs as strychnine, morphine, etc.

For the measure of temperatures the Centigrade thermometer should be, and undoubtedly soon will become, the standard for all countries, and a uniform decimal system of coinage will follow as a natural result the rapidly increasing closer commercial relationship of the nations; but, as far as the question of weights and measures is concerned, the *inidikil system* and six settings of the slide rule will "make the whole world kin."

It was George William Curtis who said, "Progress begins with the minority. It is completed by persuading the majority, by showing the reason and advantage of the step forward, and that is accomplished by appealing to the intelligence of the majority."

OFFICIAL DUTY TESTS OF PUMPING ENGINES NOS. 9 AND 10, HIGH-SERVICE STATION NO. 3, ST. LOUIS WATER WORKS, FEBRUARY 15-16 AND 26-27, 1900.

By Nils Johnson.

[Read before the Engineers' Club of St. Louis, June 13, 1900.*]

The purpose of this paper is to give a brief summary of the results obtained and the methods employed during the official duty tests of two 15,000,000-gallon triple-expansion pumping engines, designed and built by the Edw. P. Allis Company, of Milwaukee, for the Water Works of the city of St. Louis.

The pumping engines are of the vertical type, a single-acting plunger being located under each of the three cylinders. They are built up entirely of metal, being self-contained, and rest on a natural rock foundation. The depth of the pit is 28 feet and the total height, from foundation to top of steam cylinders, is 63 feet 2 inches. The total weight of each engine is 1,425,500 pounds.

The experts conducting these tests were Edward Flad, Water Commissioner of the city of St. Louis; the writer, in charge of the Construction Department of the St. Louis Water Works, and Arthur West, of the Edw. P. Allis Company, of Milwaukee. A trained crew of fifteen observers, all employes of the Water Department, took part in these tests. Eleven of them were employed as assistant engineers and draftsmen in the construction department, water works extension and the water distribution system of the water works. All of the observers, except three, have taken part in previous bonus duty tests of the pumping engines of the St. Louis Water Works, and all were well qualified for the work. The Edw. P. Allis Company had two men present besides their expert.

The specifications and the contract for these engines contain certain stipulations relating to the duty, the bonus and forfeiture as follows,—viz:

"Article 162. For the purpose of determining the efficiency of the engines furnished under this contract, there shall be a duty test of twenty-four hours' continuous run for each engine. These tests shall be conducted by the Water Commissioner.

"Article 163. The water of condensation from all steam jackets and reheaters shall be gathered and its weight carefully determined, and it shall be charged against the engines during all of the duty tests.

*Manuscript received July 14, 1900.—Secretary, Ass'n of Eng. Socs.

"Article 164. The total weight of water fed to the boilers, during the tests, shall be considered the amount of steam used, when corrected for entrainment.

"Article 165. Steam used for running the boiler feed pumps during the duty tests will be charged against the engines.

"Article 167. The head (h) to be inserted into the formula for computing the duty of the engines during the tests shall be ascertained by attaching a gauge to the discharge pipe, close to where it turns into and runs through the foundation walls of the pit, and by the elevation of the water in the wet well.

"The party of the first part hereby agrees that the pumping engines furnished under this contract shall perform, during a running test of twenty-four hours, a duty of 135,000,000 foot pounds per 1000 pounds of dry steam.

"The party of the first part further agrees that in case either engine fails to perform a duty of 135,000,000 foot pounds per 1000 pounds of steam, during the duty tests of twenty-four hours, it will pay to the party of the second part, as an agreed measure of damage for lack of efficiency of the engine, in the ratio of $2000 for each 1,000,000 foot pounds which the duty falls below 135,000,000.

"In case either engine exceeds, during the twenty-four hours' duty test, an average duty of 135,000,000 foot pounds per 1000 pounds of steam, the party of the second part agrees to pay to the party of the first part, as a reward for the superior efficiency of the engine, an amount to be in the ratio of $1000 for each 1,000,000 foot pounds which the duty exceeds 135,000,000."

The main object of the tests, as set forth by the foregoing, being that of accurately determining the duty upon which to base the payment of forfeiture or bonus, the duty formula and the quantities from which the bonus-duty was figured will first be exhibited,—viz:

$$\text{Duty} = \left(\frac{\pi d^2\ 3s\ w\ h\ r}{4 \times 144} - \left[\frac{e\ \pi d^2\ 3s\ w\ h\ r}{4 \times 144} + P\ h + F\ H \right] \right) \frac{1000}{T}$$

Where

	No. 9 Eng.	No. 10 Eng.
d = diameter of the plungers, in.........	29½	29½
s = stroke of the plungers, ft. (3 single-acting)	6	6
w = weight of one cubic foot water, lbs.	62.42	62.42
h = head pumped against, ft...........	293.1806	292.1189
r = revolutions, in 24 hours	23,716	23,659.5
e = slip of the pump valves, per cent...	0.4	0.4
P = leakage of packings of the plungers, lbs.	15,846	51,201

	No. 9 Eng.	No. 10 Eng.
F = total water fed to boilers, and pumped into tanks Nos. 6 and 7, by pump run by engines, lbs..........	218,419	215,468
H = deficiency in head pumped against by boiler feed pump, ft.............	$\frac{144 \times 47}{62.27}$	$\frac{144 \times 59.67}{62.27}$
T = dry steam furnished to the engine, by the boiler room record, lbs......	209,699	205,279
$\frac{\pi d^2\ 3s\ w\ h\ r}{4 \times 144}$ = ft. lbs. in 24 hours......	37,080,408,386+	36,858,109,558+
$\frac{e\ \pi d^2\ 3s\ w\ h\ r}{4 \times 144}$ = ft. lbs. loss by slip.....	148,321,633+	147,432,438+
P h = ft. lbs. loss by plunger packing....	4,645,739+	14,956,779+
F H = ft. lbs. deficiency in work done by feed pump	23,739,518+	29,731,885+
Duty, per 1000 lbs. of dry steam, ft. lbs.	175,984,156	178,615,389
Duty required by the contract, ft. lbs....	135,000,000	135,000,000
Bonus earned by the builders	$40,984.15	$43,615.38

It will be noticed, in the formula of the bonus-duty, that deductions have been made for losses by the slip of the pump valves, and the leakage of water through plunger packings and deficiency of head pumped against by the boiler feed pump. These losses amount in engine No. 9 to 48-100ths of 1 per cent., and in engine No. 10 to 52-100ths of 1 per cent., of the total work by plunger displacement.

It was impossible to ascertain the percentage of slip directly during the tests, on account of pumping directly into a high-pressure system. The percentage was deduced from slip tests of low-service engines 6, 7, 8 and 9 at Chain of Rocks; these pumps have valves similar to those of engines 9 and 10.

The instruments and apparatus used in the tests were carefully tested and compared with reliable standards before the tests, and several of them also after the tests.

The weighing scales were adjusted and tested to United States standard weights by the Inspector of Weights and Measures of the city of St. Louis.

The specific gravity of the mercury used in the mercury column was determined by John F. Wixford, chemist of the St. Louis Water Works, and found to be 13.5895 at 70° F. The mercury was completely volatilized when subjected to red heat, thus showing absence of non-volatile metals.

An extra revolution counter was provided and put beside the regular revolution counter of the engine. Both registered equally throughout the tests.

For ascertaining the elevation of the water in the wet well*

*The average height of the water in the wet well was 11.67 feet in No. 9 and 13.56 feet in No. 10 test above top surface of the diaphragm of suction valves.

(*i.e.*, the suction head) a float gauge was attached to the suction pipe in the engine room. This gauge was located between the wall of the wet well and the induction pipe of the circulating water of the surface condenser. For comparison and as a safeguard a gauge glass was put in the standpipe of the float gauge.

The relative elevations above city datum of the graduations of the mercury column and the gauges of the wet well were determined by precise leveling.

All pump valves were examined and tested by water pressure, and were perfectly tight before the test.

The circumference of the plungers was measured at the top, bottom and middle by a standard Chesterman steel tape. The diameters were averaged from these measurements, which were verified by calipering the plungers at the same places; the diameters thus obtained checked within 5-100ths of 1 per cent.

The stroke of the plungers was also measured by a standard Chesterman steel tape, by putting the cranks on dead centers and scribing lines on the crosshead shoes and the guides; the pressure of water on the plungers was turned off in order to guard against errors due to lost motion of the journals.

The thermometers were compared with a Hick's standard thermometer, verified at the Kew observatory.

The Crosby indicators, with the Sargent's electro-magnetic attachment for taking cards simultaneously, were used. The cards were dotted by a circuit breaker operated by hand. The dotting was expected to eliminate the pencil friction almost entirely. Nine indicators were operated simultaneously by a current of 110 volts and 2 amperes taken direct from the dynamo. At the end of every hour indicator cards were dotted continuously for one minute, and simultaneously the mercury column was read every ten seconds. The average head obtained from these readings was used in figuring the delivered horse power.

Exhibits A and B are appended for the purpose of showing the totals of the weighings of the water in the engine room and boiler room, and how closely these weighings check.

The checking of the lowering of the boiler levels is shown in Exhibit C.

Exhibit A shows that the boiler room record gives less steam chargeable to the engines than the engine room records, by 484 pounds for No. 9, and 111 pounds for No. 10 test. These discrepancies are probably due in the main to errors introduced in the readings of the gauge glass and to the fluctuations of the water level in the boilers, thus making a fictitious water level, affecting

the results with 22-100ths of 1 per cent. in No. 9 and 5-100ths of 1 per cent. in No. 10 test.

The water level in the gauge glass of the boilers was read a certain length of time at the start and ending of the tests, and the feed pump (C) kept running at a speed required to deliver back to the boilers simultaneously the exact weight of water sent away to the engines in the shape of steam.

The checking shown in Exhibit C points to the lowering of the water level of the boilers that should have taken place, assuming that the boilers and pipe connections leaked at the same rate as in the twenty-four-hour leakage test.

Exhibit B shows that the difference in the weighings in the tanks of the engine room and the boiler room was only 101 pounds during the test of No. 9 and 45 pounds at No. 10 test.

A special check sheet was kept complete every hour of the tests, checking the weighings of the water in the engine room and the boiler room, and also the amount of feed water put into the boilers and the steam sent away.

EXHIBIT A.

Boiler Room Record.

		No. 9 Eng.	No. 10 Eng.
1.	Water on hand in tank No. 6 at start of test, lbs.....	310	814
2.	Total water weighed in tanks Nos. 6 and 7 during test, lbs.	218,419	215,468
3.	Total water weighed in tank No. 8 during test, lbs..	1,704	1,704
4.	Boiler levels lowered during test, lbs...............	715	1,073
5.	Total lbs.	221,148	219,059
	Deduct.		
6.	Water weighed in tank No. 5, lbs..................	7,915	9,968
7.	Leakage during 24 hours of boilers and pipe connections, lbs.	1,716	1,704
8.	Steam blown through calorimeter, lbs.	505	456
9.	Water on hand in tank No. 6 at end of test, lbs......	836	828
10.	Entrained water in steam (by the calorimeter), lbs..	477	824
11.	Total lbs.	11,449	13,780
12.	Dry steam chargeable to engine (Items 5-11), and from which bonus-duty was figured, lbs.........	209,699	205,279
13.	Dry steam by engine room record (Items 16 + 17 + 18 — 10), lbs................................	210,183	205,390
14.	Diff. in dry steam by boiler and engine room record (Items 12-13), lbs.	—484	—111

EXHIBIT B.

Engine Room Record.

		No. 9. Eng.	No. 10 Eng.
15.	Water on hand in tank No. 2 at start of test, lbs.....	700	575
16.	Total water weighed in tanks Nos. 1 and 2 during test, lbs.	180,258	174,659
17.	Total water weighed in tank No. 3 during test, lbs...	25,130	25,691
18.	Total water weighed in tank No. 4 during test, lbs..	5,272	5,864
19.	Total water weighed in tank No. 5 during test, lbs...	7,915	9,968
20.	Total lowering of level of hot well, lbs..............	810	270
21.	Total lbs.	220,085	217,027
	Deduct.		
22.	Water on hand in tank No. 2 at end of test, lbs......	635	600
23.	Water on hand in tank No. 3 at end of test, lbs......	360	353
24.	Water on hand in tank No. 4 at end of test, lbs......	225	237
25.	Water on hand in tank No. 5 at end of test, lbs......	345	414
26.	Total lbs.	1,565	1,604
27.	Water sent from engine room to tanks Nos. 6 and 7 (Items 21-26), lbs.	218,520	215,423
28.	Water weighed in tanks Nos. 6 and 7 (Item 2), lbs..	218,419	215,468
29.	Diff. between boiler room and engine room weighings (Items 27-28), lbs.	+ 101	— 45

EXHIBIT C.

		No. 9 Eng.	No. 10 Eng.
30.	Steam blown through the calorimeter, lbs...........	505	456
31.	Water on hand at end of test in tanks No. 2, 3, 4 and 5, lbs.	1,565	1,604
32.	Water on hand at end of test in tank No. 6, lbs......	836	828
33.	Total lbs.	2,906	2,888
34.	Hot well level lowered, lbs.........................	810	270
35.	Water on hand in tank No. 6 at start of test, lbs.....	310	814
36.	Water on hand in tank No. 2 at start of test, lbs....	700	575
37.	Total lbs.	1,820	1,659
38.	Actual weight of water in lbs. the boiler level should have lowered (Items 33-37), lbs................	1,086	1,329
39.	Computed weight of water lowered in the boilers by the gauge glass, lbs...........................	715	1,073
40.	Diff. between actual and observed weights (Items 38-39), lbs.	371	156

Fig. 1 shows a trimetric projection of the piping and the weighing scales used in the tests.

Every possible precaution was taken to guard absolutely against admitting foreign water or steam to the system, by disconnecting the pipes or by inserting blind flanges in all pipes not

properly belonging to the system. All drippings and drains were taken care of by suitable piping.

All the steam having passed through the cylinders, jackets and reheaters of the engines, being condensed, was caught and weighed in tanks 1, 2, 3 and 4. The entrained water of the steam removed by the Sweets separator passed through the trap A, and the water of condensation in the steam main of engines 9 and 10 passed through the trap B, thence through a cooling coil and into weighing tank No. 5.

The jacket water of the low-pressure cylinder was also passed through a cooling coil before being weighed. The temperature of the water, when reaching the weighing tanks 3, 4 and 5, averaged 135° F. Tanks 3, 4 and 5 were covered in order to catch any possible evaporation. All the water weighed in tanks 1, 2, 3, 4 and 5 was turned into the hot well, from which it was taken by the feed pump, attached to the engine, and pumped through the filter and thence to tanks 6 and 7 in the boiler room. Tank 8 in the boiler room weighed 71 pounds of cold water each hour, to supply the amount of leakage of the boilers and piping; this being the hourly average weight of water leaking through the boilers and piping, as determined by a leakage test of twenty-four hours' duration, made before the engine tests.

Tanks 6 and 7 in the boiler room emptied into tank 9, which was connected to the suction pipe of the independent feed pump C. Tank 9 was provided with a hook gauge. The water in this tank was brought to the level of the hook gauge at the end of every hour by careful regulation of the speed of the feed pump C.

The leakage water of the packings of the main pump plungers was weighed every ten minutes throughout the tests.

The springs of the steam indicators were calibrated (see Fig. 2) by attaching them directly in their respective positions at the bottom of the steam cylinder C. The three-way cock A was turned in communication with the steam cylinder, and the piston of the indicator was kept in motion for some time, or until it was thought that all parts of the indicator had acquired the temperature due to the actual working conditions. In the meantime the steam pressure in the vessel 2 was regulated by the valve H and the drain valve L to correspond to pressures in the steam cylinder during the test.

The pressure in the vessel 1 was always carried 5 pounds higher than in the vessel 2; in order to facilitate the adjustment of the pressure in this vessel the pressure in vessel 1 was regulated by valve J and the drain valve M. Gauges K and D were carefully tested by a Crosby gauge-testing machine.

Weights were applied on the disk of the plunger Q to correspond to a given pressure. The plunger was then put in rotation by a jet of compressed air from nozzle N impinging on the vanes O of the disc. The air jet was shut off as soon as the plunger Q had attained a certain speed; the inertia kept the plunger and weights revolving. At the moment when it was found that the system was rotating in equilibrium axially, the three-way cock A was turned in communication with the vessel 2, and in turning the cock an electric circuit was closed by a projection P of the plug-cock A. The electric current passing through the solenoid F disengaged the trigger R, allowing the tension of the drum spring to rotate the indicator-drum an arc of about 43°. Simultaneously the pencil was held against the card by the solenoid G and the line corresponding to the pressure in vessel 2 was drawn.

It was found that more uniform and accurate results were obtained by gently tapping the working cylinder of the indicator, in order to avoid injurious effects of inertia and possible sticking of the piston of the indicator.

To calibrate a spring for a certain given pressure (say 80 pounds) 10 lines were traced, 5 lines with an upward floating tendency of the plunger Q and 5 lines with a downward tendency. The average of these lines was used to determine the calibration of the spring. It was not possible to catch the plunger rotating at an absolute axial equilibrium, and this method was thought to eliminate errors more completely than only drawing one line. An atmospheric line was traced for each pressure line.

Mr. Arthur West, the expert for the Edw. P. Allis Company, is the originator of this method of calibration. The arrangement of the details was worked out by Walter S. Brown, First Assistant Engineer of the Construction Department of the St. Louis Water Works.

Fig. 3 shows an apparatus for testing indicator springs, used previously by the Construction Department of the St. Louis Water Works. It is thought that the apparatus and method shown in Fig. 2 are conducive to more correct results.

The springs of the pump indicators were calibrated by a Crosby dead weight testing apparatus.

The water in the tanks 1 and 2 was weighed every 5 minutes, in tank 3 every 20 minutes, in tanks 4 and 5 and 8 every hour, in tanks 6 and 7 every 6 minutes.

The revolution counters, gauges and thermometers were read every 30 minutes. The gauge glasses of the boilers were read every 15 seconds for 5 minutes at the end and start of the tests.

The mercury column was read every 5 minutes and the wet well gauge every 10 minutes. The entrained water in the steam was determined by the Carpenters' separating calorimeter located close to the throttle.

The coal burned during the tests was weighed as it was brought into the boiler room on charging cars, and the ashes were also carefully weighed when leaving the boiler room. Fig. 11 shows the arrangement of the boiler room and the engine room of the pumping station.

The boiler tests are not indicative of the best boiler performance, as twice the required boiler capacity to run one engine was kept under fire during the tests. This was done owing to the difficulty of cutting out one single boiler and also in order to avoid irregular pressure of the steam while cleaning the fires. Consequently it is clear that the duty obtained per 100 pounds of coal is much lower during the tests than under ordinary working conditions.

The water evaporated per pound of coal under actual conditions was 5.45 pounds for No. 9 and 5.35 pounds for No. 10 test, giving an efficiency of 54.5 and 53.46 per cent. respectively; whereas, the official twenty-four-hour test of these boilers run February 10, 1898, gave an efficiency of 72.6 per cent. from Southern Illinois bituminous coal of a calorific value of 11,414 B. T. U. and 10.6 per cent. ashes.

Fig. 4 shows a front view of the pumping engines. It will be noticed that all the eccentrics of the valve motions are run by a lay shaft, located immediately above the second gallery floor.

There are two eccentrics operating the valves of each cylinder, one for the admission and one for the exhaust. The cut-off of the high-pressure cylinder is controlled by a centrifugal governor, the cut-off of the intermediate cylinder is adjusted by hand. The low-pressure cylinder is provided with a fixed cut-off.

The admission and the exhaust valves of the high-pressure cylinder and the admission valves of the intermediate cylinder are of the Corliss type, and are located in the heads of the cylinders. The exhaust valves of the intermediate and the admission and exhaust valves of the low-pressure cylinder are all of the poppet valve type with single seats. These valves are operated by cams or curved levers.

The pump valves are of medium hard rubber 3½ inches outside diameter. There are 7 valve cages in each of the suction and discharge diaphragms. Each cage is provided with 24 valves on the sides and 4 valves on top, as shown in Fig. 5. The aggregate

free area of 196 valves is 5.98 square feet, and the area of one plunger is 4.74 square feet. The suction and discharge pipes are 36 inches in diameter.

The air pump, the feed pump and the air compressor are permanently attached to the plunger of the low-pressure cylinder, and were in operation continuously during the tests.

The circulating water was taken from the suction pipe, and, after having passed through the tubes of the condenser, was returned to the suction pipe again, as shown in Fig. 6.

Graphical logs of the hourly average quantities are shown in Figs. 7 and 8, and combined cards in Figs. 9 and 10.

The data of the indicator cards and the leading dimensions of the engines, with the results computed from the quantities obtained in the tests, are given herewith, and also a "Table of Results of Tests of Pumping Engines"; this table is a partial extract from a paper, No. 833, by Prof. R. H. Thurston in the "Transactions of the American Society of Mechanical Engineers," December, 1899, Vol. XXI.

Indicator Card Data.

	9		10	
	Top.	Bottom.	Top.	Bottom.
Area of high-pressure piston....	907.92	874.32	907.92	874.32
Area of intermediate piston....	3,019.1	2,985.5	3,019.1	2,985.5
Area of low-pressure piston...	6,647.6	6,614	6,647.6	6,614
High-Pressure Cards.				
Scale of spring (manufacturer's)	80	80	80	80
Scale of spring (calibrated by Const. Dept.)	78.83	77.08	78.83	77.08
Initial pressure (absolute)......	141.72	140.87	141.35	140.26
Cut-off pressure (absolute)	141.48	140.63	141.11	138.7
Release pressure (absolute).....	42.064	45.155	42.177	41.207
Per cent. of cut-off	31.11	31.54	32.45	30.38
Mean effective pressure	53.6	54.45	55.5	52.45
Indicated horse power	145.6	142.4	149.3	136.9
Indicated horse power (total)..	288		286.2	
Intermediate-Pressure Cards.				
Scale of spring (manufacturer's)	20	20	20	20
Scale of spring (calibrated by Const. Dept.).............	19.675	19.446	19.675	19.446
Initial pressure (absolute)	40.62	40.51	41.37	41.03
Cut-off pressure (absolute)	32.91	33.37	33.56	33.84
Release pressure (absolute)	10.793	11.132	10.36	11.31
Per cent. of cut-off	36.38	36.41	32.92	34.21
Mean effective pressure	12.83	13.13	13.55	14.27
Indicated horse power	116.0	117.4	122.2	127.3
Indicated horse power (total)..	233.4		249.5	

Low-Pressure Cards.

Scale of spring (manufacturer's)	10	10	10	10
Scale of spring (calibrated by Const. Dept.)	9.877	9.389	9.877	9.389
Initial pressure (absolute)	12.64	12.67	11.56	11.35
Cut-off pressure (absolute)	8.96	8.65	8.3	8.4
Release pressure (absolute)	3.97	3.87	4.16	3.97
Per cent. of cut-off	47.22	45.79	49.7	45.5
Mean effective pressure	7.36	7.32	6.96	6.47
Indicated horse power	146.4	144.9	138.2	127.7
Indicated horse power (total)	291.3		265.9	
Total horse power, 3 cylinders	812.7		801.6	

REPORT OF DUTY TESTS OF HIGH-SERVICE ENGINES NOS. 9 AND 10.

General Data.

1.	No. of engine	9	10
2.	Date of test	Feb. 15–16.	Feb. 26-27.
3.	Duration of test, hrs	24	24
4.	Type of engine	Triple-expansion.	
5.	Dia. of H. P. cyl. in.	34	34
6.	" I. P. "	62	62
7.	" L. P. "	92	92
8.	" piston rods (2 for each cyl.), in.	4⅝	4⅝
9.	Dia. of plungers, in.	29½	29½
10.	" feed pump, in.	2¾	2¾
11.	" air compressor, in.	3	3
12.	" air pump (single-acting), in.	26	26
13.	Stroke of all cyls., plungers and pumps, ft.	6	6
14.	No. of plungers	3	3
15.	Kind of "	Single-acting.	
16.	Clearance of H. P. cyl. (top), per cent.	1.059	1.059
17.	Clearance of H. P. cyl. (bottom), per cent.	1.172	1.172
18.	Clearance of I. P. cyl. (top), per cent.	0.374	0.374
19.	Clearance of I. P. cyl. (bottom), per cent.	0.55	0.55
20.	Clearance of L. P. cyl. (top), per cent.	0.276	0.276
21.	Clearance of L. P. cyl. (bottom), per cent.	0.451	0.451
22.	Cooling surface of condenser, sq. ft.	2,102	2,102
23.	Cooling surface of condenser, per I. H. P., sq. ft.	2.59	2.62
24.	Heating surface of 1st rec. coil, sq. ft.	123	123
25.	Heating surface of 2d rec. coil, sq. ft.	176	176
26.	Vol. of H. P. cyl. (displacement) top, cu. ft.	37.83	37.83
27.	Vol. of I. P. cyl. (displacement) top, cu. ft.	125.79	125.79

General Data (Continued).

28.	Vol. of L. P. cyl. (displacement) top, cu. ft	276.98	276.98
29.	Vol. of 1st rec., cu. ft...............	184	184
30.	“ 2d “ “	365	365
31.	Ratio of areas of H. P. cyl. to I. P. cyl.	1 to 3.32	1 to 3.32
32.	Ratio of areas of I. P. cyl. to L. P. cyl.	1 to 2.2	1 to 2.2
33.	Ratio of areas of H. P. cyl. to L. P. cyl.	1 to 7.32	1 to 7.32
34.	Ratio of volumes of H. P. cyl. to 1st rec..........................	1 to 4.87	1 to 4.87
35.	Ratio of volumes of I. P. cyl. to 2d rec.	1 to 2.9	1 to 2.9
36.	Ratio of volumes of 1st rec. to 2d rec.	1 to 1.98	1 to 1.98

Pressures.

37.	Steam pressure (initial) in H. P. cyl. by cards, lbs	126.9	126.2
38.	Steam pressure in boiler room by gauge, lbs......................	129.7	130.2
39.	Steam pressure in 1st rec. by cards, lbs............................	26.2	26.6
40.	Steam pressure in 2d rec. by cards (Vac.), lbs.	1.8	3.2
41.	Steam pressure H. P. jacket, lbs.	Initial.	Initial.
42.	“ “ I. P. “ by gauge, lbs..............................	Second Rec.	Coil.
43.	Steam pressure L. P. jacket by gauge (Vac.), lbs.	2.36	0.61
44.	Steam pressure 1st rec. coil by gauge................................	H. P. Jacket.	Pressure.
45.	Steam pressure 2d rec. coil......	52.3	52
46.	Vacuum by gauge, lbs...............	14.64	14.5
47.	“ “ cards, “	14.01	14.04
48.	Barometer, lbs..........................	14.41	14.64
49.	“ in..........................	29.45	29.93

Temperatures in Degrees F.

50.	Water pumped	36	35
51.	Drain from 2d rec. (Therm. close to outlet)....................	200.5	197.2
52.	Drain from L. P. jacket (Therm. close to outlet)....................	192.7	201
53.	Water fed to boiler	76	80
54.	Water discharged from air pump	67.5	67
55.	Circulating water of condenser (in)	36	35
56.	Circulating water of condenser (out)	55	51
57.	Air in engine room	67	73
58.	Air outside..............................	15	25
59.	Exhaust steam in pipe near L. P. cyl.	97.3	98
60.	Steam (initial)..........................	325.7	325.4

Feed Water and Steam.

61.	Total water evaporated by boilers (Items 5-9, Exh. A), lbs..	220,312	218,231
62.	Total water fed to boilers (Item $5-(4+9)$, Exh. A), lbs......	219,597	217,158
63.	Total water fed to boilers per hour $\left(\frac{\text{Item 62}}{24}\right)$, lbs............	9,149.87	9,048.25
64.	Total dry steam chargeable to engine by engine room record (Item 13, Exh. A), lbs.........	210,183	205,390
65.	Dry steam to engine per hour $\left(\frac{\text{Item 64}}{24}\right)$, lbs..................	8,757.5	8,557.9
66.	Quality of steam at throttle, per cent................................	99.773	99.6
67.	Total water from surface condenser (Item 16, Exh. B), lbs.	180,258	174,659
68.	Average water from surface condenser per hour $\left(\frac{\text{Item 67}}{24}\right)$, lbs.	7,510.8	7,277.5
69.	Total water from L. P. jacket (Item 17, Exh. B), lbs...........	25,130	25,691
70.	Average water from L. P. jacket per hour $\left(\frac{\text{Item 69}}{24}\right)$, lbs........	1,047	1,070.4
71.	Total water from 2d rec. drain (Item 18, Exh. B), lbs..........	5,272	5,864
72.	Total water received from engine (Item $67+69+71$), lbs........	210,660	206,214
73.	Average water received from engine per hour $\left(\frac{\text{Item 72}}{24}\right)$, lbs.	8,777.5	8,592.2
74.	Jacket water of L. P. cyl. $\left(\frac{\text{Item 69} \times 100}{\text{Item 72}}\right)$, per cent.....	11.9	12.45
75.	Drain from 2d rec. $\left(\frac{\text{Item 71} \times 100}{\text{Item 72}}\right)$ per cent..............................	2.505	2.845

Pump Data.

76.	Total revolutions......................	23,716	23,659.5
77.	Revolutions per minute $\left(\frac{\text{Item 76}}{24 \times 60}\right)$	16.47	16.43
78.	Piston speed per minute (Item $13 \times 2 \times$ Item 77), ft............	197.64	197.16
79.	Displacement of plungers per revolution, lbs....................	5,332.954	5,332.954
80.	Displacement of plungers per revolution, gals..................	639.11	639.11
81.	Total water pumped, plunger displacement, gals...............	15,157,137	15,121,027
82.	Average head (corrected for temp., etc.), ft....................	293.1806	292.1189
83.	Total ft. lbs. of work in 24 hrs. plunger displacement (Item 76 $\times$ Item 79 $\times$ Item 82).......	37,080,408,386	36,858,109,558

INDICATOR CARDS.

84.	Indicated horse power..............	812.7	801.6
85.	Delivered horse power..............	779.97	776.27
86.	Total friction horse power (mech. and hyd.)........................	32.73	25.33
87.	Per cent. friction $\left(\frac{\text{Item 86}}{\text{Item 84}} \times 100\right)$*	4.028	3.16
88.	Total number of expansions from combined cards..................	33.89	36.06

SUMMARY AND RESULTS.

89.	Feed water per I. H. P. per hr., lbs..................................	10.8	10.719
90.	Dry steam per I. H. P. per hr., lbs..................................	10.776	10.676
91.	Feed water per D. H. P. per hr., lbs..................................	11.254	11.069
92.	Dry steam per D. H. P. per hr., lbs..................................	11.228	11.024
93.	Duty per 1000 dry steam $\left(\frac{\text{Item 83} \times 1000}{\text{Item 64}}\right)$, plunger displacement, ft. lbs............	176,419,636	179,454,255
94.	Duty per million B. T. U. $\left(\frac{\text{Item 83} \times 1{,}000{,}000}{\text{Item 98}}\right)$, ft.lbs.	155,237,451	158,077,324
95.	B. T. U. per I. H. P. per minute $\left(\frac{\text{Item 98}}{24 \times 60 \times \text{Item 84}}\right)$..........	204.37	201.96
96.	Mechanical efficiency $\left(\frac{\text{Item 85}}{\text{Item 84}} \times 100\right)$, per cent...	95.972	96.84
97.	Thermodynamic efficiency $\left(\frac{42.42}{\text{Item 95}}\right)$, per cent...........	20.781	21.003
98.	B. T. U. chargeable to engines...	238,862,518	233,165,064
99.	Actual efficiency (Item 96 × Item 97), per cent...............	19.944	20.339

*Engine No. 9 was operated 5845 hours, making 9,967,800 revolutions, and Engine No. 10 4608 hours, making 7,818,000 revolutions before the official test.

TABLE OF RESULTS OF TESTS OF PUMPING ENGINES.

	No. 9.	No. 10.					
1. Name of designer or builder	E. P. Allis Co.	E. P. Allis Co.	E. P. Allis Co.	E. P. Allis Co.	E. D. Leavitt, Jr.	Lake Erie Eng. Works.	Snow Steam Pump Works.
2. Locality	St. Louis, Mo.		Milwaukee, Wis.	Detroit, Mich.	Chestnut Hill, Mass.	Buffalo, N. Y.	Indianapolis, Ind.
3. Type	Triple Expansion.		Trip. Ex.	Trip. Ex.	Trip. Ex.	Trip. Ex.	Trip. Ex.
4. Extent of jacketing	Barrels and Receivers.		Barrels and .Receivers.	Barrels and Receivers.	Barrels, Heads and Receivers.	Barrels and Receivers.	Barrels, Heads and Receivers.
5. Name of experts conducting test	Flad, Johnson and West.		Prof. R. C. Carpenter.	Geo. H. Barrus.	Prof. E. F. Miller.	Geo. H. Barrus and Newcomb Carlton.	Prof. W. F. M. Goss.
6. Capacity, million gals., in 24 hours	15	15	18	24	20	30	20
7. Size of steam cylinders, in	34, 62, 92 x 72	34, 62, 92 x 72	28, 48, 74 x 60	28, 48, 74 x 60	137.7, 24.37, 39 x 72	37, 63, 94 x 60	29, 52, 80 x 60
8. Size of water plungers, in	29.5 x 72	29.5 x 72	32 x 60	36 x 60	Double-Acting, 17.5 x 48	42 x 60	33 x 60
9. Total heads, lbs	127.08	126.64	70.4	53.4	59.4	86.1	88.7
10. Piston speed, ft. per minute	197.64	197.16	203.1	209.9	607	207.7	214.6
11. Ratio of volume of L. P. cyl. to volume of H. P. cyl	7.32	7.32	7.1	7.1	8.3	6.5	7.7
12. Initial pressure by cards	126.9	126.2	121.4	125.2	175.7	167.1	155.6

TABLE OF RESULTS OF TESTS OF PUMPING ENGIN[illegible]ed).

13.	Cut-off press. (above atmosphere), H. P. lbs.	126.64	126.16	118.6	[illegible]4	151.5	152.2	153
14.	Release pressure L. P. cyl. (above zero), lbs.	3.92	4.06	[illegible]	5.8	6.9	7.4	6.4
15.	Back pressure L. P. cyl. (above zero), lbs.	0.4	0.6	1.[illegible]	2.8	1.5	2.2	2.5
16.	Cut-off H. P. cylinder, per cent..............	31.32	31.41	33.7	33.8	38.4	32.3	31.5
17.	Clearance H. P. cylinder, per cent............	1.116	1.116	1.4	1.4	1.5	1.4	1.8
18.	Ratio of expansion by volumes..................	22.7	23.4	20.4	20.3	21	19.6	23.8
19.	Indicated horse power..............................	812.7	801.6	573.9	573.7	575.7	1185.5	775.5
20.	Friction, per cent..	4.028	3.16	9.2	10.2	10.5	5.1	4.6
21.	Dry steam per I. H. P. per hour, including jackets and reheater, lbs.........................	10.776	10.676	11.68	12.52	11.22	12.39	11.26
22.	Per cent. of steam condensed in jackets and reheaters..	14.4	15.3	9.2	12.7	17.1	13.7	10.5 est.
23.	Dry steam per I. H. P. per hour, exclusive of jackets and reheaters..........................	9.223	9.021	10.61	10.93	9.3	10.7	10.8 "
24.	Steam accounted for by indicator, H. P. cut-off, lbs..	9.0255		9.05*	9.5	8.5*	9.1	8.7*
25.	Cylinder condensation, including jacket and reheater, at cut-off, H. P. cylinder, per cent..	16.2		22.5	24.1	24.2	26.6	22.7
26.	M. E. P. referred to L. P. cylinder, lbs......	20.62	20.58	21.77	21.03	26.36	27.19	23.65
27.	Duty based on 1,000,000 B. T. U., expressed in million foot pounds..................	155.2	158.7	137	129.7	141.9	135.4	150.1
28.	Duty based on 1000 lbs. of dry steam, expressed in million foot pounds.............	176.4	179.4	154	142.4	154.9	152	167.8

* Calculated by G. H. Barrus.

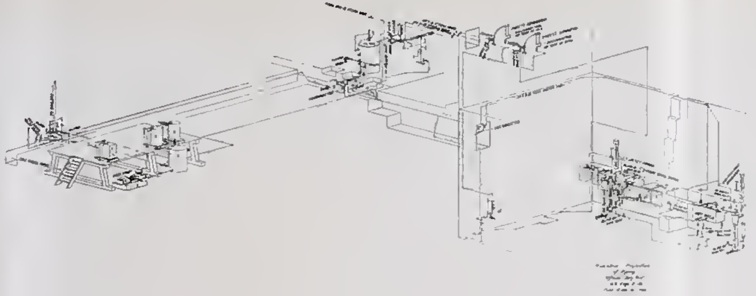


Fig 1 Piping, Tanks, Etc.

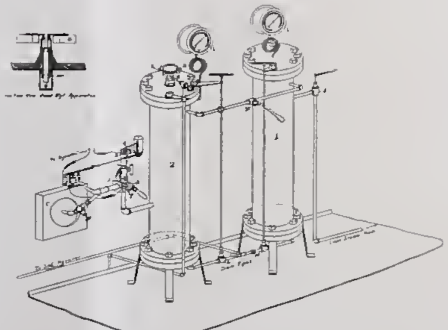


Fig. 2. Apparatus for Calibrating Indicator.

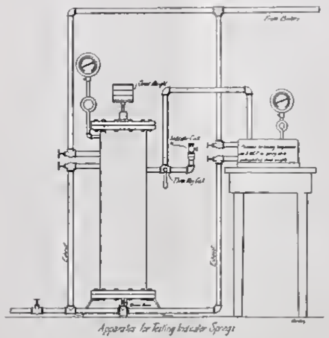


Fig. 3. Apparatus for Testing Indicator Springs.

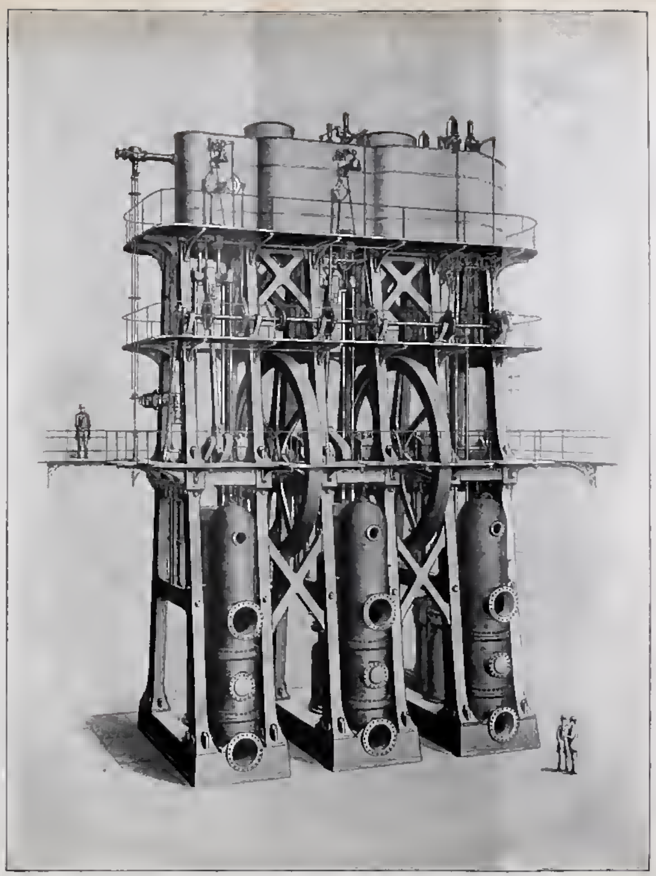


Fig. 4 Vertical Triple-Expansion High-Service Engines.

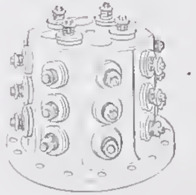


Fig. 5. Valve Cage.

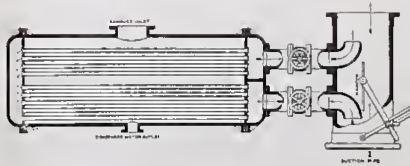
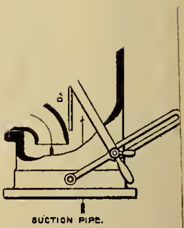


Fig. 6. Method of Circulating Water Through Condenser.



.er Through Condenser.

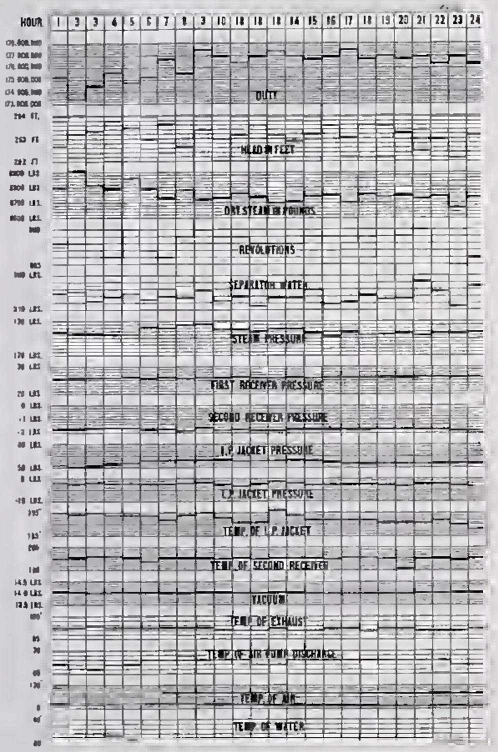


Fig. 7. Log of Test, Engine No. 9.

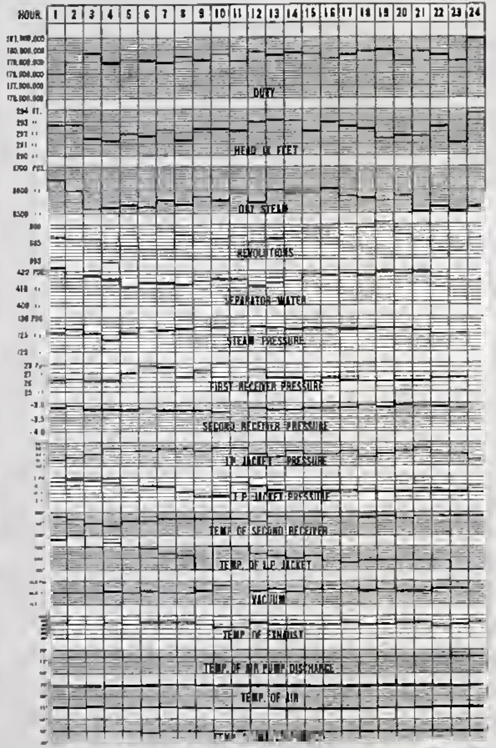


Fig. 8. Log of Test, Engine No. 10.

Fig. 9. Combined Steam Indicator Diagram, Engine No. 9.

Fig. 10. Combined Steam Indicator Diagram, Engine No. 10.

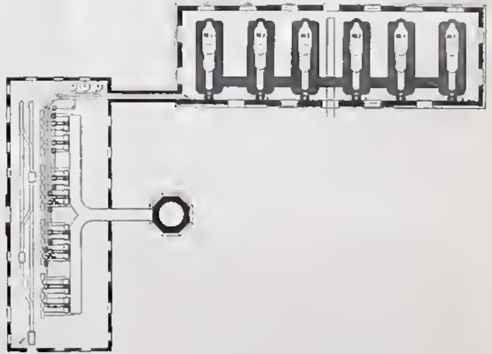


Fig. 11. Plan of Engine and Boiler Rooms.

-er Rooms.

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THE WATER POWER AT HOLYOKE, MASSACHUSETTS.

BY HORATIO A. FOSTER, MEMBER ENGINEERS' SOCIETY OF WESTERN NEW YORK.

[Read before the Society, June 4, 1900.*]

IN these days of the transmission of power by means of electricity the search for good and reliable water powers has become a sort of engineering fad, and the numbers of them that are exploited and brought to the attention of capitalists is something to be wondered at. Many of them are so far from users of power as to make it discouraging to invest the necessary money, and others are so variable in their flow of water as to make them very unreliable, compelling the installation of an auxiliary steam plant to insure continuity of operation.

Incidentally, it may not be known to all present that the Government, during the census of 1880, caused examinations to be made of nearly all the water courses east of the Mississippi River. The territory was divided into districts, and an expert placed in charge of each. Every important river and stream was examined from its mouth back to its source; each and every fall was described, whether developed or not; the flow of water at the different points was gaged, and many other useful data were reported.

Fifty years ago there were very few large water powers developed, and comparatively little was known of the modern means of using water power. Railroads were new, as were also most of the conveniences with which at the present day we would find it difficult to dispense.

*Manuscript received June 11, 1900.—Secretary, Ass'n of Eng. Socs.

The water power at Holyoke, Mass., was developed more than fifty years ago, and has been in continuous operation ever since. From a very small farming village there has developed one of the strongest and most industrious manufacturing communities in the United States. Although a large portion of the product of Holyoke is fine paper, there are many other products, notably cotton cloth, cotton yarns and spool cotton, one of the largest factories for the manufacture of the latter article being located there.

At Holyoke the Connecticut River, more than 300 miles long, makes an abrupt bend, which is almost a true half-circle. Originally there were rapids around this bend, with a total fall of 60 feet from one end of the semicircle to the other.

In 1847 the Legislature of Massachusetts was petitioned by Thomas H. Perkins, George H. Lyman, Edmund Dwight and others for an act of incorporation for the Hadley Falls Company, "for the purpose of constructing and maintaining a dam across the Connecticut River and one or more locks and canals in connection with said dam; and for creating a water power to be used by said corporation for manufacturing articles from cotton, wood, iron, wool and other materials, and to be sold to other persons and corporations to be used for manufacturing or mechanical purposes, and also for the purpose of navigation." The capital stock was $4,000,000. The Hadley Falls Company purchased the property and franchise of the South Hadley Falls Lock and Canal Company, and land in the region amounting to 1100 acres.*

At this time (1847) there were fourteen houses, a grist mill, one little shop and one cotton mill lying in the region now covered by the city of Holyoke. It is also recorded that a wing dam was built out into the stream in 1831, and a small mill run by the power thus developed.

The first dam was begun in 1847 by building a coffer dam of cribs filled with stone. I quote the following description of the coffer dam from data furnished by a resident of South Hadley Falls:

"The coffer dam was built by loading cribs with stone, gravel, etc., and sinking them about four rods above the line of the great dam. The bed-piece was formed of four stretchers. The sills were very large timbers, 40 or more feet long, which were intended to be bolted to the bedrock, but there was a good deal of blocking up under some of them. In some places it was necessary to blast rock out under them; in other places it was necessary to put blocks

*In 1859 the Hadley Falls Company was succeeded by the present corporation, the Holyoke Water Power Company.

under and use longer bolts. The sills were 6 feet apart from center to center; the posts were framed into the sill and into the stretcher, and each section was raised on its sill like the side of a house or barn. The roof of the dam was covered with 4-inch hemlock planks. All timber and planks were hemlock. The overfall was 12 feet long, of 1-foot timbers, and covered with plank same as the other side of the dam. The crest of the dam was covered with boiler iron in strips 6 to 8 feet long."

This dam was destroyed and washed away the first time it was filled. The event of the completion of the coffer dam in 1848 had been anticipated by the public, and special trains were run to accommodate those who wished to see the first flow of water over it. The pond filled very slowly, and it was three o'clock in the afternoon when the dam gave way under the strain. The structure broke from its foundations, turned over and, with the exception of 75 feet at one end and 150 feet at the other, was swept downstream by the great volume of water.

There was some interesting reading about this event at the time, and, without burdening this paper with much of it, I think the following series of telegrams sent at the time by a Mr. Davis, who was interested in the corporation, will be fully appreciated. The dispatches were in the order given, but only the last one is vouched for as being verbatim:

"10 A.M.—The gates were just closed, and the water is filling behind the dam."

"12 M.—The dam is leaking badly."

"2 P.M.—The stones of the bulkhead are giving way to the pressure."

"3.20 P.M.—Your old dam has gone to hell by way of Willimansett."

Even to-day the destruction of so large a piece of work would be very discouraging, but the discouragement seems to have been very short-lived at that time; and the work of reconstruction was immediately commenced. The wreck of the old dam was cleared away, and in 1849 preparations began for the second dam. This dam forms the upstream triangular section of Fig. 1.

I quote as follows from a pamphlet published some years ago:

"In April of that year (1849) two coffer dams were built, one on each side of the river, and each extending 200 feet from the bank into the stream. They were completed in May, the water pumped out and the rock excavated to a depth of 6 feet. The construction of the main dam was then begun by laying down three 15-inch square sticks lengthwise across the river. The dam was

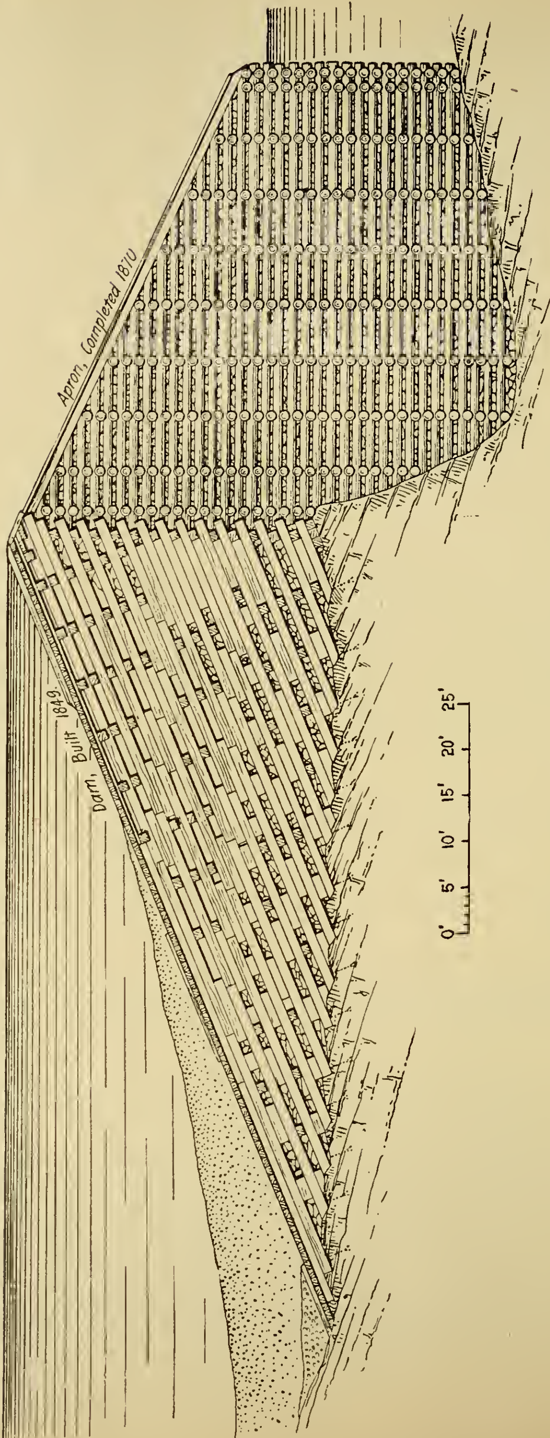

FIG. 1. SECTION OF OLD WOODEN DAM.

Figs. 1–6 are reprinted, by permission, from *Engineering News* of May 13, 1897.

started in sections 6 feet from center to center, and, as the river is 1019 feet wide at that place, there were 170 sections. These sections were connected or tied to each other by 12-inch square sticks running across the river. The structure above the foundation sticks was made up of alternate courses of these ties and rafters, also 12 inches square. Between the rafters, in the same course with the ties, short blocks were introduced to stiffen or prevent the bending of the rafters. At the splicings of the rafter long pieces were put in, treenailed to the rafter with eight 2-inch treenails of oak. The foot of each rafter was scribed and bolted to the rock with $1\frac{1}{4}$-inch iron bolts. The structure was thus reared to its full height of about 30 feet, and its upstream surface covered with 6-inch plank with the exception of a space 16 feet wide by 18 feet long, which was temporarily left open. The toe of the dam was secured by placing a second covering of plank at right angles with the first, with the lower end scribed and bolted to the rock. Except the space temporarily left open, this structure was filled solid with gravel. Four feet of the crest of the dam on the upstream side was covered with boiler iron $\frac{3}{8}$ inch thick, for protection from ice and driftwood.

"In this manner 400 feet of the dam were completed, 200 feet on each side of the river. As the summer advanced another section of 200 feet was added to each side, leaving but 217 feet open for the water to run through. A coffer dam was then built covering this space of 217 feet, and the water of the river allowed to run through the four spaces 16 feet wide left for the purpose in the four previously constructed sections.

"After the completion of the middle section of the dam the last coffer dam was removed, and preparations made to stop the temporary openings through the structure, which was done by gates hinged to the planking. These gates were closed on Monday, October 22, 1849, two alternate gates being first closed by knocking out a prop which held them parallel with the water, and an instant later the other gates were closed in the same manner.

"The flow of water through the temporary openings was stopped at about 12.30 midday, and it was not until ten o'clock at night that the water began flowing over the full length of the dam."

In order to insure the permanency of this dam all the open spaces were filled and closely packed with stone and gravel to a height of 10 feet, and the planking of the upper portion of the dam was doubled to 18 inches of solid timber.

The dam is founded on a ledge of red sandstone and slate, which dips downstream about 30° from a horizontal plane.

The bed of the river was graveled for 70 feet above the dam, and this graveling carried some 30 feet over its sloping surface, which lies at an angle of about 20° from the horizontal, and is 92 feet in width from the foot to the crest of the timber. This dam is said to have cost about $150,000.

The bulkhead at the west end of the dam is 140 feet long between the end of the dam and the shore, and 46 feet wide. In this bulkhead are located the head gates, which are operated from a gate house extending along its top.

This dam has withstood the wear and tear since it was built, and is still standing, in spite of the fact that a new cut-stone dam has been built a short distance below it. It has, however, had some troubles. An examination in 1868, after a very heavy freshet, showed some bad leaks, and it was found that the water falling over the crest of the dam had washed away the ledge underneath and in front of the structure to a depth of 20 to 25 feet (see Fig. 1), and that the eddies caused by the falling water had turned logs and ice back against the structure and had broken away many of the timbers and part of the rock to such an extent as to imperil its permanency.

To check this action, in 1868, 1869 and 1870, another large crib-work structure (see Fig. 1) of greater volume than the original dam was built in front of it, and tied to it as solidly as possible. This structure is of round logs in pockets 6 x 6 feet square, which were filled with stone; and its top was covered with 6-inch planks of hardwood sloping downstream. The slope of this apron being about parallel with the dip of the rock, the erosion of the bed of the stream further down was still carried on, and at the time of starting the new stone dam about 20 feet of the bedrock had been worn away. This new apron cost between $250,000 and $350,000.

With the exception of this apron, but little repairing was required from the time the dam was erected until 1879, when a break in the plank top occurred; and between that year and 1885 there were so many leaks of this nature that 20 feet of the upper surface was replanked; and at the same time a line of sheet piling was driven the whole length of the dam some distance back from the face. This sheet piling was gravel-puddled on both sides, with the idea of making the structure water-tight. All these repairs were accomplished in sections by building a coffer dam about 100 feet long around a section of the main dam.

Since 1885 numerous small leaks have started, and a large amount of gravel seems to have been washed to the river bed below, indicating that the permanent tightness of the structure was threat-

ened. There have been but two large breaks, however; one occurring in 1893, and another a year later. The first was a hole, approximately 4 x 6 feet, about 11 feet vertically below the crest, which was repaired by dropping over it a gate 8 feet square constructed of two layers of 3-inch chestnut plank. The excess of size of this cover was due to the necessity of reaching a solid bearing at two adjacent timbers of the structure, which are 6 feet between centers.

The second hole was not quite so large, being about 4 feet square, and was repaired in the same manner. The leakage gradually increased until in 1895 it amounted to 118 cubic feet per second, or, at a total head of 60 feet, 800 gross horse power.

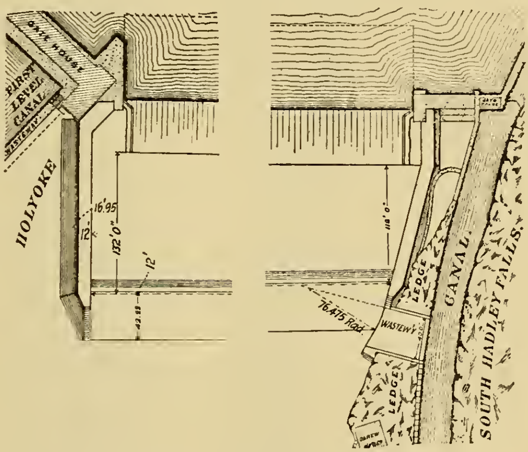

FIG. 2. PLAN OF OLD AND NEW DAMS.

In the year 1891 the Holyoke Water Power Company decided to construct a new stone dam as near the old one as convenient, and of such design as would be as nearly permanent as possible. Surveys were begun that year, and, owing to the erosion of the river bed immediately below the apron of the old dam, the nearest location was found to be 132 feet at the southerly end and 112 feet at the northerly, measured from the toe of the apron to the line of the top of the stone dam. The total length of spillway is 1020 feet between abutments, and the old dam is to be left where it is, the space between the two gradually becoming filled, making a solid dike more than 150 feet wide and nearly as permanent as the surrounding hills. (See Figs. 2, 3, 5 and 6.)

The abutment at the south or Holyoke end (see Fig. 5) starts at the old gate-house bulkhead and runs at right angles with the line of the old dam. Its top extends just beyond the top of the

new dam, whence it is stepped down to the toe of the structure. This abutment is 12 feet thick on top and 28 feet thick at the bottom. The top is 12 feet above the level of the dam, or 42 feet above the bedrock. Like the dam itself, this and the north or Hadley Falls abutment are constructed of heavy rubble masonry, laid in rich Portland cement mortar. On its south side and top, and for 17 feet down from the top on the north or water side, this abutment is faced with cut granite blocks of large dimensions.

Owing to the shape of the ledge, and to a canal location at the north end, the north abutment is skewed at an angle of about 15° with the line of the dam, and between the top and toe of the new dam a wasteway is built over the ledge of rock, the drop face of which curves in with a radius of about 76½ feet, the fall of the wasteway being about half on the lower slope of the dam, the rest falling into the river.

The north abutment, where not built against the ledge, has the same dimensions as the other.

As said before, the dam itself is 1020 feet long at the spillway. It is 30 feet high above bedrock at the back face, and the bottom course on bedrock is 54.22 feet wide from the back line to the tip of the toe on the downstream side. (See Figs. 5 and 6.) The back face is stepped off one foot in five all the way to the top as a batter, the steps affording a footing for the coffer dam. The rear part of the top is beveled for a width of about five feet, beginning at a point 2 feet below the crest and running to a point on top 2 feet back of the center line. There is then a level space 2 feet wide to the center line, and from that point the face of the spillway begins in a parabola, the form of curve being that which would be taken by a body of water 4 feet in depth flowing freely over the crest. This curve extends down the face of the spillway to the point of reversal, where it takes the form of a cycloid or the "curve of quickest descent" to the bottom at a point 34.89 feet from the center line, thence rising to the toe 7.33 feet beyond to a height of 0.98 feet above the bedrock, in order to break the fall of water and to prevent as far as possible the erosive action on the river bed. The face of the spillway has been left rough.

The body of the dam is constructed of heavy rubble masonry laid in rich Portland cement mortar, with beds inclined somewhat from the horizontal, the downstream side being the highest. The spillway, back face and 5 feet of the top are faced with heavy granite blocks, those on the lower part of the spillway being fastened together with galvanized iron dogs, while those on top are secured together with galvanized iron dowels. There are some 34,500 cubic yards of rubble masonry in the entire structure.

The excavation in the bed of the river was done by the company by day work, and took three years, being completed in 1896. The trench for the toe of the dam was excavated to an average

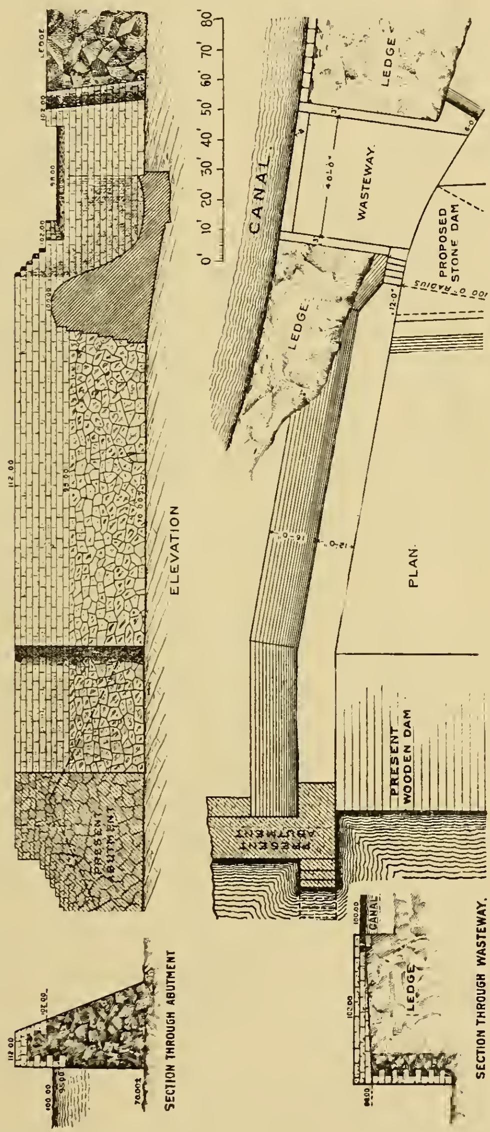

Fig. 3. Details of Dam at South Hadley Falls End.

depth of 8 feet, and from 15 to 18 feet in width, the bottom being leveled off by a bed of concrete for the reception of the masonry. Back of this the rock was roughly stepped to afford a good bearing for the rubble masonry. The bedrock is partly blue slate and partly

red sandstone, and about 13,000 cubic yards were removed. In order to drain this excavation during construction a trench 600 feet long, about 17 feet wide and 10 feet deep was excavated, beginning at a point near the center of the river and running downstream parallel with the flow of water.

Seldom have specifications been so carefully drawn as were those for this work, and the call for copies was so great that some six hundred have been distributed. Doubts were expressed by many engineers and contractors as to the requirements being exactly fulfilled, but, owing to strict interpretation of the specifications and most rigid inspection, the result has been exactly as required, and the work stands to-day a monument to its engineers.

The stone for rubble masonry was taken from the river bed below the dam. The granite is from a quarry at Vinal Haven, Maine, and the cement was furnished by the Alpha Cement Company, of Philadelphia.

The rubble was laid with full joints, while the granite was laid with joints but $\frac{1}{4}$ inch wide, the mortar being one part cement and two parts sand.

Every piece of granite was laid by instruments for line and grade, and the batter was obtained from templates supplied by the company.

The dam was constructed in four sections, the south end and a center section just north of the drain channel being built up for a considerable height first. Then a coffer dam was built on the first level of the north channel, thus turning the water through the center channel, while a section of dam 5 feet high was constructed behind it. The coffer was then transferred to the center channel, and a section 10 feet high built in that opening. In this way the alternate sections were built in until the structure was complete. The cost of the entire work is said to have been between $600,000 and $700,000.

Up to the time of the development at Niagara the Holyoke water power was the largest in the United States. The drainage area of the Connecticut River above Holyoke is about 8000 square miles, and the average daily flow during 1895 was 11,951 cubic feet per second, or 82,000 gross horse power. The minimum power of the river at Holyoke has been estimated as 30,000 horse power, but is now called 22,000.

The system of distributing canals (Fig. 4) is laid out on the plain inclosed by the bend of the river, and consists of three levels, the fall between the first and second levels being 20 feet; that between the second and third level 12 feet, while the fall from the

third level canal to the river at its average stage is 28 feet. Between the marginal canals and the river the fall varies from 23 to 28 feet, according to locations and the stage of water.

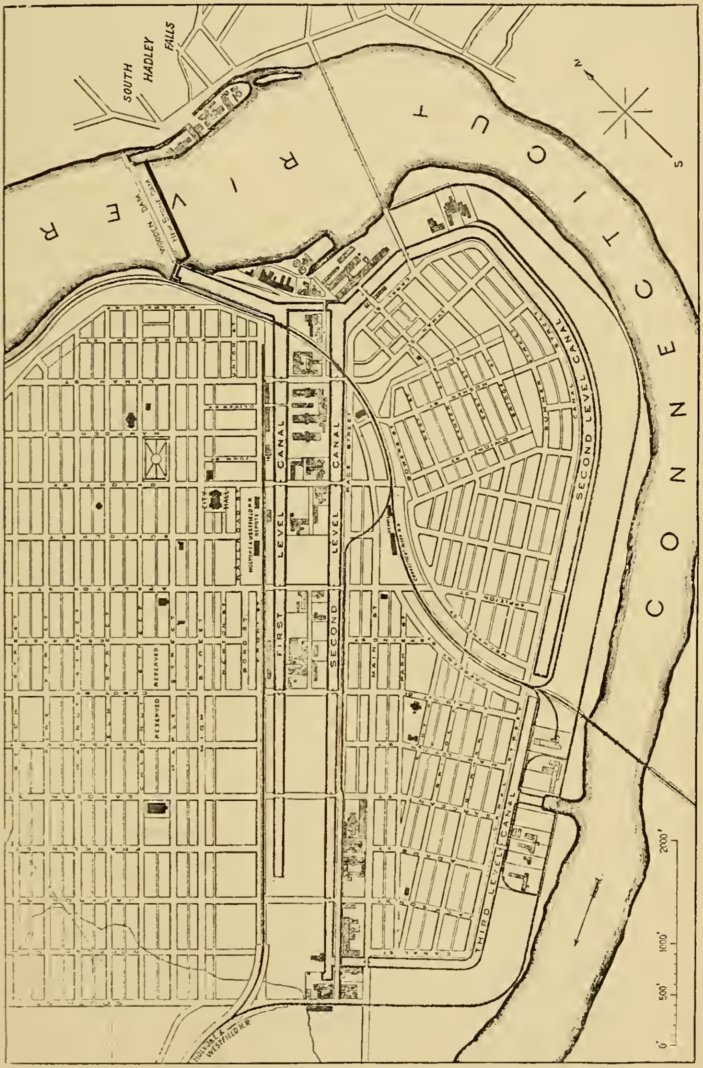

Fig. 4. Partial Plan of City of Holyoke, Showing Dams and Canals.
Shaded Areas are Manufacturing Establishments and Public Buildings.

The head gates in the bulkhead are fourteen in number, twelve of them being 9 feet wide and 15 feet deep, while the remaining two are $4\frac{1}{2}$ feet wide by 11 feet deep. All are operated by gearing actuated by a turbine in the abutment.

A waste weir just below the gate house disposes of surplus water in the canal. Careful watch is kept upon the level of the

water, and more or less is let in through the gates in order to maintain as nearly as possible a constant level, no matter what the quantity used may be.

The main or upper level canal (Fig. 4) extends in a southerly direction for about 1000 feet, then turns at an obtuse angle and runs southwest for about a mile. For the first run of 1000 feet this canal is 140 feet wide, and the water is 22 feet deep. The width decreases from the bend at the rate of one foot in every 100 feet of length.

The second level canal, beginning at a point some distance beyond the extreme end of the first level, runs parallel with it, at a distance of about 400 feet to the northeast, and serves as a raceway for the mills taking water from the upper level. At the east end of this course it turns and runs directly east for a distance of about 800 feet. It then follows the course of the river for about a mile and a quarter at a distance of about 400 feet from it, the margin of land between the canal and the river serving for the location of mills. The second level canal is 140 feet wide for about 2000 feet, but converges to a width of 100 feet at each end. Mills along the south end of this level take water from it and waste into the third level canal, which, starting at a point opposite the south end of the second level, runs southeast for about 1000 feet, then, making a right angle turn, it runs back up the river and parallel with it until it meets the end of the second level. The depth of water averages 15 feet. The third level is 3550 feet long, 100 feet wide and 10 feet deep.

Waste weirs are so located along the canals as to dispose of any surplus water.

The charges for power and the method used for computing it are perhaps the most interesting points about this great enterprise, and it may be well to give some space to the discussion of charges for power generated by water.

The general public has become so accustomed to buying supplies, whether cheese, gas, coal or electricity, by meter, that the fact that water power has been almost invariably sold at a flat rate, based upon a maximum use, which cannot be exceeded, has been overlooked. Speaking of electricity, only recently has the point been fully and plainly brought out that the method of charge by meter is not fair to consumers or to producers, and consequently measures have been taken to remedy this defect. Owing to the fact that the storage of electricity for any great supply is not practicable, a straight meter charge for current does not take into account differences in manner of consuming current as bearing

upon the fixed expense of supplying that current. For instance, a large factory using light for about one hour per day would require the electric plant to be kept ready for its supply. It would, then, have to be large enough for the continuous supply of this maximum demand, although the payment by the factory, under a straight meter charge, may be no greater than that by another customer who consumes the same number of meter units by using his lights for a greater number of hours, and who therefore requires but a small plant for his supply. It is true that the *operating* expense of the electric plant per unit will be practically the same in both cases, but it is readily seen that the *fixed* expense per unit for supplying the large factory must necessarily be greater than that for the other customer. These studies have resulted in a more rational method of charging for electricity, and, after having been in use by some of the municipally owned plants in England for some years, this method is now used by most of the large plants throughout the United States.

The same argument bears on the charges for water power, as nearly all of the expense for such power is fixed, even the labor being practically the same whether the whole or any part of the plant employing the power is in use, and whether loaded fully or in part.

It may be fairly argued that in the past those consumers (such as paper mills and textile manufacturers) who located on rented water powers had occasion to use continuously whatever amount they required, yet nearly all other industries use a varying amount of power, the aggregate of which is always less than the maximum for which they pay. In comparing the cost of steam power with that of water power, it has been very common to compare the *average* amount of *steam* power developed with the *maximum* amount of *water* power paid for, which is manifestly unfair; but on most of the older water powers the rental has been so low for the maximum demand as to leave no chance for comparison with steam by any method. For instance, in Holyoke, since all the power available has been rented, growing industries have had to provide for extensions by erecting steam plants, and, as coal sells at wholesale for about $4.00 per ton, these plants have usually been designed for the greatest economy, and steam power has been produced at a very low rate. Notwithstanding this fact, the water power in use would, under no conditions, be exchanged for the best steam plant that engineers have been able to install.

The marvelous development of electrical transmission of power has changed all the old conditions, and now the power of the water-

fall, developed on the spot, is sent to the point of use over slender wires, rather than through expensive canals, and the room needed for power appliances can now be used for productive purposes.

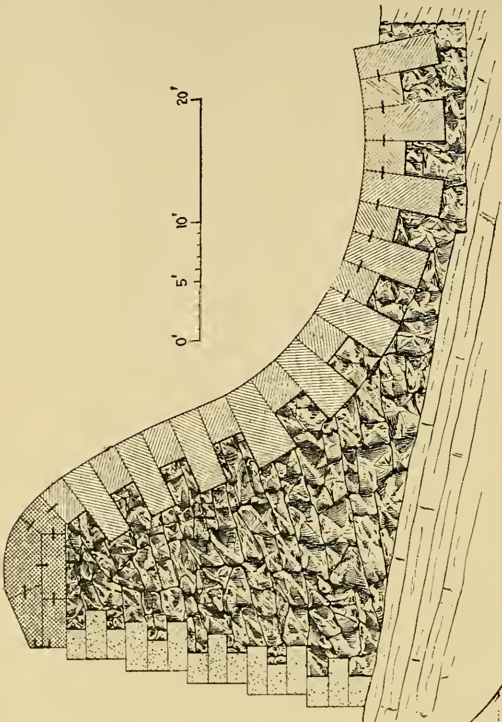

FIG. 6. CROSS SECTION OF DAM.

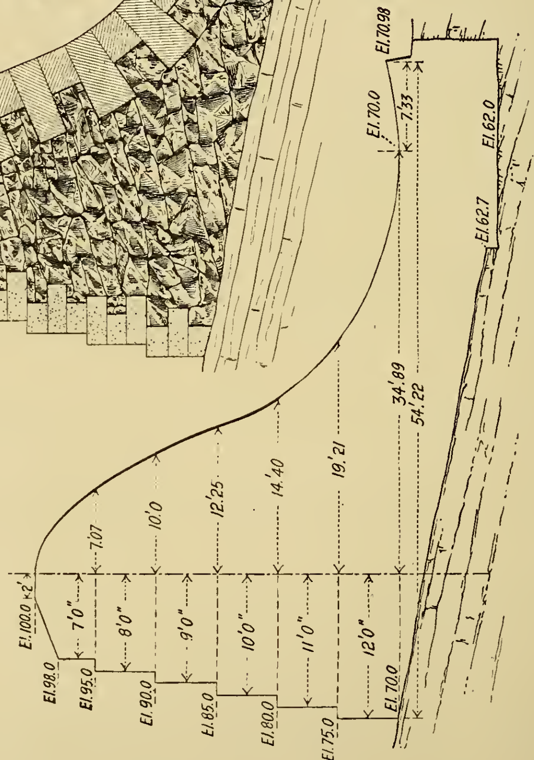

Fig. 5. Outline Section of Dam.

Naturally the question of method and amount of charge becomes more important than ever, and, as the industrial uses to which the power is put are more varied in character and apt to be greater in number and smaller in demand, the rates have to be readjusted to fit

the circumstances. It is obvious that where there are a great number of customers using varied amounts of power at different periods of the day or season, it is possible to make use of the same power plant machinery for supplying a number of such demands, the aggregate of which, if they were continuous, would be much greater than the maximum capacity of the power plant, and it is therefore not necessary, even working close to the theory, to charge each customer with the whole fixed expense for the amount of plant which he may call for at times; but this charge can be divided according to the load factor,—*i.e.,* to the proportion which the average demand bears to the maximum capacity of the plant, or the proportion which the maximum demand made upon it bears to the capacity of the plant. While the variable expenses of the ordinary water power are so small, in comparison with the fixed expense, as to be negligible, and while, therefore, in the case of the more diversified distribution nearly always resulting from electrical transmission, the charge to be made results finally in a flat rate for a stated amount of power, yet it is more practicable to make a certain portion of the charge flat and uniform for the maximum demand, and then make up the remainder on a sliding scale based on the total number of units consumed as shown by the meter.

All these points were carefully studied when rates were made for the Niagara Falls Power Company and its connections, and the result was the card with which you are all doubtless familiar, and which is based upon the theory just advanced.

The grants of the Holyoke Water Power Company to its customers (for they are grants rather than leases) are especially interesting in that they are made perpetual, and are recorded in the registry of deeds at the county seat in the same manner as any other deed.

The grant is made for water power, but every grant carries with it the right to the land necessary for the erection of buildings; and the price is based wholly and only upon the mill powers of water, and not upon the amount of land involved.

The original grants were apparently made with the idea that it would take many generations to use the full capacity of the river. These leases cover what is now called *permanent* power, and the consideration for this was originally a lump sum, sometimes called a bonus, of $5000 per mill power and an annual rental of $450 per mill power forever. Each of these leases carried with it the right to draw 50 per cent. more water than was specified, and for this a charge is made of $2.50 per mill power per day and $2.50 per night, being substantially $1500 per annum per mill power;

and at the present time every owner of a permanent mill power uses his full surplus privilege.

I quote as follows from the proposal issued by the power company to its customers such articles as refer to the rental of the power:

"Article II. Each mill power at the respective falls is declared to be the right, during sixteen hours in a day, to draw from the nearest canal or water course of the grantors, and through the land to be granted, 38 cubic feet of water per second at the upper fall when the head and fall there is 20 feet, or a quantity inversely

FIG. 7. HOLYOKE DAM, APRIL 20, 1900. WATER 9 FEET 7 INCHES DEEP ON CREST OF DAM.

proportionate to the height at the other falls. And in order to prevent disputes as to the power of each mill privilege in the variations of the height of the water from changes of the seasons or other causes, it is understood and declared that the quantity of water shall be increased in proportion to the reduction of the height, one foot being allowed and deducted from the height of the actual head and fall, and also from that with which it is compared before computing the proportion between them. Thus on a head and fall of 32 feet the quantity of water to be used would be 23 9-31 cubic feet per second, and the respective parties, where either has any lawful interest therein, may at all reasonable times, in a peaceable manner, and after due notice to the principal steward or agent then

on duty at any mill, enter the raceway thereof to measure and compare the quantity of water with the quantity granted; and in the measurement all wastage shall be included. And may also adopt and use such other mode of making or verifying the said measurements as the circumstances of each particular case may require."

After going on to say, in other articles, that the grantors must forever keep in good repair, etc., the canals, and must forever maintain a dam across the Connecticut River, and that the grantees shall maintain in good repair the flumes and raceways, Article V reads:

"In order to continue in the grantors an interest in common with the grantees for the preservation and support of the mill powers which may be granted, and to secure a fund to indemnify the grantees for expenses which may be incurred by them for making repairs, if the grantors should improperly neglect to make them, it is proposed that part of the consideration of every sale, and all that is to be allowed the grantors for the repairs, etc., by them assumed, should be paid or secured to them in the form of a reservation of rent. *It is therefore declared* that each mill power, with the land to which it is annexed, shall forever be subject to a perpetual annual rent of at least 260 ounces, troy weight, of silver of the present (1859) standard fineness of the silver coin of the United States, or an equivalent in gold, at the option of the grantee at the time of payment; which rent is to be paid in yearly payments forever, free from all charges or deductions whatever for taxes or assessments of every description which may be assessed or levied upon any granted premises after the making of the deed, all of which are assumed by the grantees. And a perpetual annual rent, at last equal to the above, shall be reserved for every mill power hereafter sold."

After the full power of the river at its lowest stages was sold to consumers there remained, during the greater part of the year, a vast surplus of water, which it was, of course, policy to use, and the power company instituted what it designates as non-permanent leases, or power which is not guaranteed, but will be supplied when there is more than a sufficient quantity of water in the river to supply all the permanent power, together with its 50 per cent. surplus. The rate of charge for non-permanent power is a bonus of $4500 per mill power and an annual rental of $1500 per mill power, with a pro rata rebate on the rental for such time as the water may be too low to use.

At times of low water the power is not so divided between the consumers of non-permanent power that they may have a constant supply in proportionally reduced amount, but each in turn receives the full leased power for a proportionately reduced time. The result has been that the average rebate in time has not much exceeded twenty days per annum, and during many years has been as low as six or eight days.

Permanent power is practically guaranteed forever, except in case of accident obviously not the fault of the grantors, in which case proportional rebate is made for the time during which the power is not ready for use. Should the power be stopped owing to carelessness of the grantors, then the customer would be entitled not only to rebate, but also to suit against the grantors for damages.

In closing, let us briefly review the effect which the development of this great water power has had upon the community immediately interested.

Starting with the construction of the dam, there were fourteen houses and three small mills located upon the site of what is now the great industrial city of Holyoke. The village was incorporated as a town in 1850, and as a city in 1873. In the year 1865, sixteen years after the establishment of the dam, the population numbered 5648, and the total valuation was $3,130,342, of which the greater part must have been the property of the water power company. In 1898, thirty-three years after, the population had increased to 44,982, an increase of 696 per cent., and the valuation to $36,424,460, an increase of 1064 per cent. Few booms in the new West exceed the increase here shown, and scarcely one could equal it in the solidity of its established industries.

Going back over the history of this corporation, the record of its results, the growth of the city in population and wealth, all of which practically owes its existence to the establishment of the dam, it is perhaps not surprising that there are so many water power projects being brought to the attention of investors at the present time.

HIGH-WATER PROTECTION METHODS ON LOWER MISSISSIPPI RIVER.

By William Joseph Hardee, Member American Society Civil Engineers; Member Louisiana Engineering Society.

[Read before the Louisiana Engineering Society at adjourned regular meeting, June 18, 1900.*]

The preservation of the levee line on the lower Mississippi River during periods of high water is a most important subject and is worthy of much thought and attention to avoid the numerous and costly mistakes which have been made in the past. When the method under which that character of work was done during past years is considered, it is most surprising that so much success was achieved and that the mistakes which were made did not prove more extensive both as to cost and disaster.

Up to the present time there has been no well-defined organization for the systematic conduct of high-water protection work. The nearest approach to anything like systematic, intelligent and harmonious co-operation on the part of those engaged in such work was during the flood of 1897; but this was far from satisfactory and is susceptible of great improvement.

The absence of anything like system will be readily appreciated when it is remembered that there are engaged in the work some six practically independent agencies—the district levee board, the Parish officials, the State officials, the United States officials, the railroad officials and the individual planter. At the present time not one of those agencies has the available resources with which, alone and unassisted, to care for the levee line during an extraordinary flood.

The local district levee boards are charged by law with the responsibility of preserving at all times the integrity of their respective levee lines; and, except in a few instances, this charge has been intelligently executed; but there have been occasions when the task has vastly exceeded the resources of the several boards.

If those boards had possessed ample means, they would to-day have the levee line of their respective districts in condition to resist successfully the biggest flood so far experienced without the necessity for an amount of work in excess of their means. But they have not possessed adequate means to accomplish this end, and it is a fact that while the levees have been steadily improved, the

*Manuscript received June 25, 1900.—Secretary, Ass'n of Eng. Socs.

floods of the past have found them in an imperfect condition, and a great amount of work of an emergency character, has been necessary to successfully preserve them during high-water periods. On such occasions the other agencies have been requested to assist, or they have voluntarily proffered assistance by reason of their indirect connection with the cause and their general interest in the work.

It is a strange fact that each of the other five agencies, when rendering assistance, seemed to claim superior wisdom, and usually insisted, not infrequently to the disadvantage of the work, on proceeding according to its individual judgment. Confusion was the inevitable result, and from confusion sprung wastefulness and insubstantial work, sometimes accompanied by disaster.

Confusion, attended by wastefulness and insubstantial work, has oftentimes been due to a lack of forethought or proper advance consideration. In some instances expensive arrangements were made, and large quantities of perishable materials were provided for prospective high-water protection work which never materialized. On other occasions the magnitude of a flood was neither anticipated nor appreciated until, figuratively speaking, the last minute, and then the necessary work had to be done hurriedly and frequently under the adverse conditions of bad weather, resulting in increased cost and less stability.

Based on his observations and experience, the writer believes that, with the resources at command, a system for economically and efficiently preserving the levee line during flood periods can be devised.

It is not considered advisable, however, to advocate a system which would involve the combined resources and efforts of the entire six agencies referred to, because, depending on time and circumstances, the resources of those agencies vary. A more practical system would be such a one as would involve one agency only, with adequate means prosecuting it, and then, as occasion would demand, the necessary work may in advance be divided and certain functions allotted to the different agencies according to the practicability of applying the resources of each.

The old maxim, "In time of peace prepare for war," applies with equal force to the preservation of levees. If it were practicable to do so, the levee line should, during low-water period, be put in such a condition that the usual cases of emergency which now arise would be in great part, if not altogether, removed. It is hoped that, with advancing years and the continued expenditure of large sums of money, this happy condition will be realized at no very distant date.

But, taking the levee line as it stands to-day, there are certain kinds of high-water protection work, as will be more fully described later on, incidental to every flood in excess of a stage which puts 3 feet or more of water against a levee. The full extent of protection work is, of course, governed by the size and duration of the flood. If it were possible to anticipate the approximate size of a flood, a large amount of work could be more substantially done and at a minimum cost. As a matter of fact, a flood in the lower Mississippi River can be anticipated within reasonable limits, and far enough in advance of its realization to permit the deliberate execution of a large amount of preliminary protection work.

An approximate relationship exists between adjacent water gages on the Mississippi River when the flood surface of that stream is not disturbed by crevasses or augmented by the waters from tributary streams. For instance, a certain maximum at Cairo will produce a certain maximum at Memphis, the next prominent gage station below. A gage, however, below a tributary stream, may be affected by a flood poured out of the tributary, but, as there is an approximate relationship between a gage so affected and the next gage below, comparisons may be successively carried on until the place is reached at which a forecast is desired. The great bulk of the water which produces a flood in the lower Mississippi River is derived from the Ohio River and the Mississippi River itself above Cairo. A flood out of any of the tributary streams—St. Francis, White, Arkansas, Yazoo or Red—does not materially add to the height of a flood in the Mississippi. The effect of a flood from any one of those streams is rather to prolong the passage of a coincident flood in the Mississippi than to increase its height. Of course, floods poured simultaneously out of all those streams or out of each stream at or about the time that the crest of a coincident flood wave in the Mississippi passed its mouth would materially increase the height of the flood in the latter stream. But the records since and including 1890 do not show that such a coincidence of floods has occurred. They show, however, that some only of the tributaries contributed more or less to the height and duration of the floods of 1890, 1892, 1893 and 1897. On the other hand, the Mississippi River may be abnormally depressed below the mouth of Red River, as has sometimes occurred, on account of Red River being low and a large volume of Mississippi River water in consequence thereof being drawn off by the Atchafalaya River.

As the great floods emanate north of Cairo, that place can properly be considered the strategic point, and the Cairo gage can be accepted as a fairly reliable index to what will follow on the

lower Mississippi. A wave, such as we are concerned with, in so far as it bears on the subject-matter of this paper, occupies from ten to fourteen days in passing from Cairo to Vicksburg, so that we always have that much advance notice of what is coming. The tributaries, of course, should be closely observed, and proper allowance should be made for any influence they might exert.

It is the writer's opinion that no damage can befall any of the existing levees when there is less than 3 feet of water against them. But at about the 3-foot stage the pressure is sufficiently great to commence developing weaknesses due to faulty construction, unequal shrinking or leaks caused by burrowing animals. It, therefore, follows that unless a flood in excess of that 3-foot stage is experienced, there is no need for protection work of any kind; but, as soon as it is evident that the 3-foot or higher stage will be experienced, preparations for a high-water campaign should be immediately begun, and conducted as the conditions attending the expansion of the flood demand.

The battures or foreshores vary in elevation with respect to the high-water surface at different places along the river. The ground is usually higher near the edge of the bank than it is at the levee, so that a flood which covers the ground near the edge of the bank puts several feet of water against the levee. The water usually finds its way to a levee through depressions and drainage ditches, and, with few exceptions, is well against the levee before the entire foreshore is fully overtopped.

The following is the approximate height which will put 3 feet of water against a considerable length of the levee line in the vicinity of the respective gages, though a foot or so less in height will put 3 feet of water against short lengths of levee: Vicksburg, 42 feet; St. Joseph, 38 feet; Natchez, 44 feet; Red River Landing, 42 feet; Bayou Sara, 37 feet; Baton Rouge, 34 feet; Plaquemine, 29 feet; Donaldsonville, 26 feet; College Point, 23 feet; Carrollton, 12 feet. The gage at Fort Jackson is not included, as its elevation is so often influenced by wind and tide.

It is now in order to ascertain what height at Cairo culminates in 42 feet at Vicksburg and 42 feet at Red River Landing.

A comparison of fifteen gage observations selected at random shows that for stages of 25 feet or less at Cairo the time consumed in the passage of the crest of a wave from Cairo to Vicksburg varies from four to eight days. But as we are interested only in stages which culminate in 42 feet at Vicksburg, a comparison of lower stages should be disregarded.

On account of the closure of St. Francis basin during recent

years, flood waves which occurred prior to 1898, and which were in excess of bank full stage, should be disregarded, as they would prove misleading. A comparison of all the flood waves of consistent elevation, since and including the year 1894, shows that 42.7 feet at Cairo will culminate in 42 feet at Vicksburg, and that the time of passage varies from ten to fourteen days, a fair average being twelve days. These figures include an addition of height and prolonged time of passage due to augmentation by water from the St. Francis and White Rivers, which is almost invariably coincident with a flood of the elevation we are discussing in the Mississippi River.

Storms which occur in the Valley of the Ohio River usually originate west of there, and, in their passage, traverse the territory drained by the St. Francis and White Rivers.

The probable maximum height which the gage at Cairo will reach may be estimated with fair accuracy by considering the gages at stations north of that place on the Ohio and Mississippi Rivers and their tributaries, so that by a series of deductions it is possible to secure more than twelve days' notice of what is to be expected, as well as to forecast beyond the 42-foot stage at Vicksburg.

The records show that at the time of the year when the gage at Vicksburg reaches 42 feet Red River and its tributaries are usually low, from which it may be safely inferred that 42 feet at Vicksburg cannot be expected to culminate in more than 39 feet at Red River Landing; the time of passage may be placed at two days though on an average it is a fraction less.

It must, therefore, be noted that high-water protection work of some kind will be necessary under the proposed system between Vicksburg and Bougere (lower terminal of the levee system of the lower Tensas district), before work of any kind will be necessary below Red River Landing.

Ordinarily,—*i.e.,* when the Red River and its tributaries are low, as is usually the case,—the gage at Vicksburg must read 46 feet to produce 42 feet at Red River Landing.

Failure of levees usually results from one of the following seven causes:

1. Insufficient height, which permits the water to flow over the top of the levee, cutting it away.

2. Leakage due to faulty construction; to uneven shrinking or sinking, or to the operations of burrowing animals resulting in the formation of cracks or holes, which, under some conditions, rapidly enlarge as the water flows through them.

3. Sloughing, due principally to some defect in the body of

the levee, which permits the water to percolate too freely through it, and which, being attended by defective drainage on the land side, results in the land slope becoming saturated and so softened that it will not stand.

4. Sinking, the result of the levee having been built on an unstable foundation, generally of a quicksand character, which, under the influence of excessive wetting and the pressure exerted by the weight of the embankment, is displaced and causes the embankment to subside into the cavity thus created.

5. Wave-wash, which, when the river is made rough by wind or by passing steamers, attacks the surface of the levee not protected by a close growth of grass.

6. Excessive erosion at salient angles due to removal of all of the old levee, causing abnormal velocity of the current, which washes and cuts away the controlling embankment.

7. Cutting due to operations of malicious or insane persons.

INSUFFICIENT HEIGHT.

Earthen embankments, no matter how well protected by a growth of sod, will be destroyed by water flowing over their tops for any considerable length of time. It is therefore, absolutely necessary, to keep the top of the levee well above the water surface. To assure this, the levee line should, if practicable, be maintained at a uniform grade, even if the cross-section of the embankment cannot at the same time be given the standard dimensions of 8 feet crown and 6 feet of base to each foot of height. All of the low lengths of the levee line should be brought to the standard grade well in advance of high water. The work can be done then not only at much less cost, but so much more substantially, and the cost of protecting the new work with washboards will be saved. This matter was seriously considered just after the flood of 1897, but, owing to the long length of low levee line, and the limited amount of money available for levee improvement, nothing much was done beyond a length of about five continuous miles by the United States in the Lower Tensas District and a few miles by the Atchafalaya Board scattered throughout its district.

The length of low levee has since then been greatly reduced; it is believed that it is now practicable to raise all of the remaining lengths of low levee to standard grade during the coming construction season. But if this is not done before a flood is in sight which will overtop the low lengths of levee, as soon as a conclusion as to the probable height is reached, which should be as far in advance as possible, the topping or "capping," as it is commonly

designated, should be put on with teams and scrapers. Work done in this manner generally costs less and has the advantage of greater compaction and is in consequence much more substantial than earth placed by handbarrows or wheelbarrows. To postpone the capping until the water is near, or actually on, the crown of the levee, or until the land in the rear becomes submerged by seepage or rainwater due to defective drainage, is taking an unjustifiable risk, and entails an avoidable increase in the cost of the work.

Whether the capping be put on by teams or by other means, it should be protected with washboards against erosion by the waves. In the past capping has been protected by sacks filled with earth or cotton-bale bagging carefully placed along the front surface of the capping. This method should be abandoned; it is more costly and less substantial than wooden washboards. If the capping is put on by teams, the washboards can be most advantageously placed after the earth is in place; but if the capping is put on with wheelbarrows or handbarrows, the washboards should be put on in advance of the earth.

The washboards should consist of 1 x 12-inch x 12-foot lumber, placed parallel to the levee, standing on the 1-inch side and about one foot from the river edge of the crown. The washboards should be held in position by two lines of 2 x 2-inch pickets sharpened and vertically driven at least 15 inches in the levee; two pickets should be driven for every six lineal feet of washboards, one on each side of the boards and with just space enough between to permit the comfortable adjustment of the boards. Each board should be nailed at top and bottom to each picket. The writer has personally directed the placing of many miles of washboards, and has seen much of that kind of work done by others. Sometimes on account of scarcity of materials, or in an endeavor to economize on cost, single pickets only were placed, or double pickets at the junction of boards only, with a single picket at the half-way point between, and the boards were sparsely nailed or the nailing was altogether omitted. These latter methods are falsely economical and should not be practiced. The greater security obtained by the use of double pickets and full nailing will amply compensate for the cost of the additional materials.

Weakness in some of the capping which has been placed in the past has resulted from inattention to small details. In the first place, the portion of the crown of the levee to be occupied by the capping should be thoroughly broken up so as to make a good bond with the new earth. Without such bond there will be free leakage across the line of junction, particularly in the case of thickly sod-

grown embankments. Care must be taken to see that each bottom board touches the levee throughout its length and that it is well pressed into the levee to prevent any under wash; the washboards should otherwise be firmly and securely set, for they are often and for long periods subjected to heavy strains by the waves beating against them, and if not made secure they will work loose. As soon as they get loose and are weakened by the waves they cause the earth behind them to loosen and crumble and wash under the bottom boards, and soon the entire capping is destroyed. Care should be taken to tamp the earth in light layers as it is placed against the washboards, to insure a close union of the two. Otherwise rain-water and over wave-wash water will percolate through the soft earth, impair the union and ultimately weaken, if not wholly destroy, the capping. The top of the capping should be sloped towards the rear from where it joins the washboards, so that both rainwater and over wave-wash will promptly run off.

LEAKAGE.

Leakage is due to either faulty construction, unequal shrinking or sinking, or burrowing animals, and constitutes one of the most perplexing problems a levee engineer has to deal with during high water. Leaks are more or less treacherous, and are both difficult and expensive to stop.

Failure to properly clean and then break up with a plow, or otherwise, the surface of the ground to be occupied by the base of the levee, to insure a perfect bond between the embankment soil and the natural soil; or failure before construction commences to remove all foreign substances which might in after years decay and leave a cavity; or the introduction of foreign substances into the embankment at the time of its construction, may result in leaks.

In some instances, where old levees have been razed in building new levees or where they have caved into the river, the writer has observed in the body of the embankment, large cavities, which could have been produced only by the rotting of a wooden barrel or wooden box or a pile of logs. He has also observed a clear line of demarcation between the embankment soil and the natural soil, indicated by a stratum, two inches or more thick, of partially decayed leaves and trash. This stratum must, by reason of its composition, be permeable, in which case leakage would be free, and, after the trash and leaves would be deposed, the soil of the embankment or the soil of the ground would be attacked and eroded in proportion to the strength of the flow of water through the channel thus created.

There need be but little apprehension in the future from leaks originating in the several manners described. During the past ten years a large percentage of the levee line of the Fourth Engineer District, Improving Mississippi River, has been built anew, and the remaining lengths have been so substantially enlarged as to almost entirely eliminate original defects; the system of inspection has been rigid, and it is not probable that the embankments contain any defects of construction.

Unequal shrinkage cannot easily be provided against. It usually manifests itself in cracks extending in almost every conceivable direction, and its occurrence is most frequent in embankments built of buckshot or clayey materials or in embankments built of those materials and sand, alternately placed in thick bodies or layers. The degree of inequality of the shrinkage seems to be governed entirely by the amount of moisture in the soil when it is put into place.

The earth near the bottom, sides and top of a crack, usually expands when moistened. If it is wetted by slow degrees the crack will usually close up. The greatest danger attending a crack occurs when the soil surrounding it remains unwetted for several years during which time the crack increases in size, and, if a large volume of water be suddenly thrust upon it, the soil will rapidly wash and the crack increase in size until it finally causes the embankment to collapse. Unequal shrinking is rare in embankments built wholly of loam or sand.

The levees should be carefully inspected just before or soon after the water has gotten against them, and, if cracks are found they should be filled and rammed with loose earth, particularly and most carefully on the intake side. If a crack is not discovered until the water is well against the embankment, the exposed portion should be treated as above, and clods, mixed with loose earth, should be dumped into the water over the crack until the flow of water has been entirely cut off.

Lateral cracks in a levee are sometimes caused by the sinking of a section of embankment built on a bad foundation, while the adjoining section, built on a good foundation, stands firm. Such cracks are usually large and conspicuous, and should be repaired during low water. If not repaired then, they should be treated exactly as has been described for cracks produced by unequal shrinkage.

The attention which has been devoted to draining old burrow pits, neighboring sloughs, etc., has resulted in a large reduction of the nocuous operations of burrowing animals, by destroying their

harbor and breeding places, causing them to migrate to localities more favorable to their pursuits. But the evil still exists to a troublesome degree. Burrowing animals do not work with great success in sandy soils because the walls cave in behind them; it is in clay that they do their best work. For that reason we find few levees built of sandy soils cut up with leaks made by burrowing animals. This kind of leak is mostly found in buckshot or clay levees; a compensating advantage exists in the fact that such soil does not easily erode and a single hole is not always dangerous. If it is no larger than two inches in diameter it will do no damage as long as its size does not increase. It should be carefully watched, and, as long as the water it discharges is clear or free of sediment, all is well. But if it discharges muddy water or a considerable quantity of sediment, such action is plain evidence that the hole is either a very direct one or that it is enlarging by erosion, or that an animal or animals are somewhere at work in it. It has then become a menace to the safety of the levee and should be promptly treated.

The greatest danger to be apprehended from holes through any kind of a levee is the presence of a large number of them within a small area. As the holes enlarge, the intervening volume of earth is correspondingly reduced; individual enlargement results in several holes working into each other and becoming one hole, and this process of conversion, if not checked, may continue until numerous small holes have become one large hole beyond control.

Plugging a hole is rather a simple matter if the intake end of the hole can be located, but to stop a good-sized leak at the discharge end is tedious, expensive and uncertain. The intake end of a hole which discharges out of the land slope of the levee or at the base of the levee, or just beyond the base of a levee, may be several hundred feet distant from a point immediately abreast of it on the river side, or, if approximately abreast of it, a hundred feet or more distant from the base of the levee. There being a well-defined channel affording a line of least resistance, the water flows along that line. But as soon as the discharge end is obstructed another line of least resistance develops, probably a minute channel connected with the main channel, which, under the increased pressure, rapidly enlarges and the water bursts out elsewhere. The flow continues as before, not infrequently to a greater extent if the flow line has been made more direct.

The writer has determined the location of the intake end of a hole by the use of unslacked lime. This method is very tedious, and is not practicable if a large area must be investigated. If un-

slacked lime be dropped into the water just over the intake and is sucked into the hole, that fact will very shortly be manifested by the water discharged by the hole. In order not to confuse the location of the intake, small areas of ground only can be covered at a time.

The use of lime is valuable in some instances, and is recommended to determine if the hole be direct; that is, if its intake end is immediately abreast of the discharge end and within reasonable working distance from the base of the levee. The position of the intake end of a hole largely governs the method which should be employed to stop the leak. In the majority of cases the intake end of a single hole is so far removed from the discharge end that it is impossible to locate it. When numerous holes exist within a small space the intakes are nearly always just abreast of the discharge ends.

It is not considered possible to define a method for universal application in stopping leaks. Nearly all leaks have to be cared for according to their individual characters, and this can come to him in charge only by long experience. The experienced physician does not always need a thermometer and pulse test to determine that a patient has fever; something almost intangible, in the appearance of the patient, the odor of the room and other things, make the fact apparent to him. So it generally is with the experienced levee engineer; he seems to know intuitively whether a hole is dangerous, as well as how it should be cared for. However, some general rules apply to the stoppage of leaks, particularly to the avoidance of expensive and worthless work, which may augment rather than reduce the danger.

A common method for stopping leaks, when the tools and materials are available, is to drive with a dolly, or light hand pile driver, a single line of sheet piling (2 x 12-inch boards tongued and grooved or otherwise prepared to make close joint) into the river slope of the levee or into the ground just at or immediately beyond the base of the levee to a sufficient depth to encounter the hole or holes, and thus cut off the flow of water. This is a certain and comparatively inexpensive remedy if the holes can be encountered, but if the holes are not covered the work is worthless and its cost will have been wasted. Sheet piling should therefore not be employed when the river side position of the hole cannot be definitely located.

As dollies have not been extensively used along the river, a brief description of them is pertinent. A dolly is a stick of square or rectangular shaped timber of varying size and length, according

to the driving power desired, near to the outer end of which, at proper working distances apart, are nailed cross-strips or handboards to furnish convenient grasp for raising it. The inner end rests on the ground or a platform, and is held in position by several stakes or pegs driven about it, the ground end being but slightly lower than the outer end to maintain the dolly on something like a horizontal plane. Enough men are put at the handboards to readily raise the outer end of the stick several feet above the object to be driven. The stick is raised and sharply let fall alternately until the object is driven to the desired depth. Great care should be observed in selecting the position for the sheet piling with reference to the location of the leak or leaks and the character of the soil composing the embankment. The very least possible penetration by the sheet piling is desirable, to reduce vibration and avoid weakening the embankment by cracking or loosening it. In dealing with soils which easily crack or loosen when penetrated, the sheet piling should never be driven into the body of the embankment. Sheet piling should also be driven in the shortest possible time.

During the flood of 1892 a crevasse was caused by inexperienced men driving sheet piling into the embankment at Tessier's Plantation, Pontchartrain District. There were three 3-inch holes in the levee at that place, discharging within a few feet of each other at the land base of the levee. These holes had existed for some years, and had been frequently observed. In those days many such leaks existed at numerous places in that levee district; a few only of them were considered to seriously menace the safety of the levee, and those few were cut out when the river was low. But the great majority were allowed to remain undisturbed. Just before the flood reached its maximum stage, some of the leaks which had been allowed to continue showed serious symptoms, and the Levee Board decided to stop all of them. In this task a number of the bridge gangs of the Yazoo and Mississippi Valley Railroad were employed. A small gang of men, without experienced direction, commenced work during the afternoon driving sheet piling into the river slope of the embankment at Tessier. Mr. J. W. Ross, a near-by resident and ex-member of the levee board, has since told me that he was present during a part of the afternoon the sheet piling was being driven; that before any of the piling was driven the holes were discharging clear water, free of sediment, and that the holes gave no evidence that enlargement was in progress; but that after a few planks had been driven the holes commenced to discharge muddy water and large quantities of sediment. There was no relief gang, and work was discontinued at nightfall, at which time

some six or eight pieces of plank had been driven. At about nine o'clock that night the levee collapsed, and the river poured through the opening. There is scarcely a doubt that the piling cracked and loosened the earth in the embankment, causing it to erode rapidly, and that the sheet piling was the direct cause of the failure of the levee.

Another, but more costly method for stopping leaks having their intake ends on the front slope of the levee or within reasonable working distance of the base of the levee, is to drive vertically two lines of 1 x 12-inch boards, not necessarily arranged to make close joints, from 3 to 6 feet apart, (distance regulated by height of structure) with just enough penetration to furnish good toe hold, sufficiently braced longitudinally and laterally to afford required rigidity. This structure is built in a continuous length from the levee to a point beyond the intakes and back to the levee, and, after the woodwork has been completed, the interior formed by the two lines of plank is filled with earth. The structure is commonly called a mud-box. Sometimes, owing to scarcity of materials or to inexperience of those doing the work, a single line of 1-inch plank was driven, and the entire space between it and the levee was filled with loose earth or sacks filled with earth. This form of structure is called a bulkhead. It is manifest that either bulkheads or mud-boxes, like sheet piling, are worthless unless the sore itself—the intake end of the hole—is reached and covered. The writer has seen a large amount of all three of the kinds of work described which failed to accomplish any good.

Of the three methods named, sheet piling, when practicable, is recommended. It is equally effective, less expensive and most quickly put in place.

When a hole develops serious symptoms and its intake end cannot be located, it must be treated in the most substantial manner possible at the discharge end.

During the flood of 1890 the writer experimented with light sheet iron cylinders of different lengths, having a diameter varying from 10 to 18 inches; they were equipped with soldered handles at intervals to afford good hand hold. To reinforce the cylinders at the base about ten cubic yards of earth was piled in conical shape about the hole, a small drain being left temporarily to take off the water flowing through the hole in the levee. As soon as the earth was in place the iron cylinder was clapped over the hole and forced into the ground by the weight of as many men as could get hand hold. The surrounding earth was simultaneously tamped about the cylinder. Not more than two out of a dozen of the cylinders

proved successful; none of the large ones, over large holes, were successful. The water at first rose rapidly in the cylinders, but gradually diminished in rate until it stopped rising altogether. Generally the water found a line of less resistance, and broke out through the ground only a few feet away.

The common method of treating a leak at its discharge end is by building what is locally termed a "horseshoe," which is nothing more than a mud-box, such as has been already described, built on the land side of the levee, and of such length as may be necessary to leave a good margin of ground on all sides of the leak. While it is expensive, this method is certain in its results if the levee is not too largely infested with leaks, and is recommended in cases of serious leaks when the intake end cannot be definitely located. In the past, when lumber was not available and sacks were at hand, "horseshoes" were constructed by pyramiding sacks filled with earth. Such a structure is unnecessarily expensive, and should be discountenanced.

During some of the past floods the writer has known short lengths of levee to be so infested with leaks that application of all the several remedial measures, which have been mentioned, did not assure the safety of the levee. In such cases collapse was anticipated, and, to provide against disaster, several lines of cribs (the number of lines being regulated by the depth of the water in which the structure was placed) were built and filled with sacks filled with earth. In other words, the crevasse was closed before it occurred. The cribs were so placed as to extend well beyond the base of the levee and at both ends to join sound embankment.

These very bad places were the result of neglect; of failure, when the river was low, to cut out leaks which were known to exist but which were allowed year by year to extend and enlarge until the levee became thoroughly rotten and scarcely more water-tight than a sieve.

The improved condition of the levee line and the attention which is now usually devoted annually to repairs and maintenance warrant the belief that such extreme cases of bad levee, as have just been described, are things of the past.

The treatment of leaks should in the future be more simple and at the same time, less expensive than in the past. To-day much more is known of their character and how to deal with them; and the best remedy only of the past should be applied until some more successful remedy is evolved. It is contemplated, of course, that none but experienced men will direct the work, and that suitable materials with which to do the work properly and economically will at all times be at hand.

The foregoing remarks refer to leaks of an ordinary character, but as very extraordinary leaks sometimes occur, it is thought advisable to describe one that came within the writer's experience and how it was treated, as under similar circumstances the same treatment would seem to be best and should be applied. The following is quoted from my report of the 1897 flood:

"During the morning of April 27, when the water was at 52 on the Vicksburg gage, a large leak developed under the Clagget levee (644-R). At this place both the levee and surrounding soil are light loam. In the rear of the levee within 30 feet of its base there is an old burrow pit about 8 feet deep with almost vertical side next to the levee. Without previous warning a 6-inch stream of water spurted out of the wall of the pit midway its height; it did not merely run out and trickle down, but shot out as if ejected from a hose. Its force was so great as to churn the water into foam in the pit into which it was discharged. There are many theories as to the origin of this leak, but its cause will never be known unless the embankment should be cut and the hole traced."

"It is more than likely a series of disconnected holes or small cavities existing under the levee, due either to burrowing animals or decayed vegetation, or probably both, and under the pressure of water there was leakage from one to another, attended with a certain amount of wash which continued until the several holes were connected and made a free passage for the water through one large channel where the water burst out as described."

"A large force was immediately summoned, and a semicircular wall of sacks built about 6 feet high around the discharge end. The interior space rapidly filled, and the sacks were soon overtopped. In the meantime a large force of teams was put to work, and a run around commenced about 100 feet in rear of the main levee and designed to be about 250 feet long when completed. An opening was left in it as an outlet for the overflow until the new embankment was thought sufficiently high with proper cross-section to hold the filled basin, then the opening was closed. The basin filled rapidly at first, then more slowly; at the end of two days it was found that the basin was still filling, and would overtop the run around. The teams resumed work, and the embankment was raised 3 feet. The basin continued to fill, but as the river commenced falling in a few days, further raising was not necessary. It now stands with an 8-foot crown, about 2 to 1-inch side slopes, and a grade about 3 feet lower than the highest point reached by the river."

SLOUGHING.

When water has stood against an earthen embankment for a sufficient time to saturate it, there is always considerable seepage caused by the river water percolating through the pores or interstices of the embankment. The amount of seepage is usually governed by the porosity of the soil composing the embankment. Seepage is not usually free in embankments composed of clayey materials; when seepage does seem to exist in them to a considerable extent, it is more properly leakage due to cracks in the embankment caused by contraction in drying out or to unequal shrinkage. Seepage is freest in embankments composed of sandy soils; the coarser the grain of sand the freer the seepage, because the soil does not become sufficiently compacted during the time the embankment is constructing to render the mass impervious to water. Voids are of large or small size, depending on the coarseness of the grains of sand. Under water pressure the voids soon become connected and form numerous minute channels, which wash and enlarge as the flood is prolonged or the pressure increased by greater height.

Seepage produces a general softening or rotting of the land slope of the embankment. The soil at this point often becomes semi-fluid, and, if the slope be steep, a part of the embankment will slough or slide out, producing a corresponding loss of cross-section. The writer has never known a first slough to extend higher up than one-half of the slope of the levee. If the seepage be not stopped, a second slough will occur higher up as soon as the face made by the first slough has been reduced to a semi-fluid condition; this action will progress in steps until the embankment has sloughed across its entire cross-section as far as the water. Its action being progressive, sloughing does not constitute an element of great danger, for there is always ample time to stop it; treatment is simple if the principles involved be understood.

To arrest sloughing, good land-side drainage and stoppage of the seepage are essential. A competent drain ditch should be cut, about 2 feet clear of the base of the levee, to conduct the seepage water as frequently as possible to some natural line of drainage in the rear of the levee. Additionally, numerous small V-shaped gullies, an inch or so only wide and deep should be cut in the land slope of the levee to promptly deliver the seepage water to the drain ditch. The position and size of the drain ditch and gullies should be such as to assure the removal of the seepage water as fast as it comes through the embankment, for if this water is allowed to stand, the land slope will not become water-soaked and its integrity will be preserved.

The next step is to stop the seepage; this is effected by dumping loose earth into the water in sufficient quantity to cover the submerged front slope with a blanket of fresh soil several inches thick, the coarser particles of which will be sucked into the interstices or small channels. These soon expand from wetting, and shortly the seepage will be "choked." The layman who sees this work in progress will immediately classify dumping loose earth in the water as sheer nonsense, but, as a matter of fact, the good effect will manifest itself in a short while after work has been commenced; at first by reduced seepage, a little later by entire stoppage and ultimately by the mass drying out and showing no further inclination to move.

If sloughs be treated when they first occur, or, better still, before they occur, when their approaching occurrence is clearly indicated to the experienced eye by the presence of excessive moisture on the land slope, much annoyance and expense can be avoided. As the treatment of sloughs is necessarily expensive when a number occur in close proximity and the supply of labor is limited, they may be only partially instead of wholly treated; that is, in lieu of putting a large enough blanket of loose earth on the river slope of the levee to provide against further seepage during the entire flood period. Only a small blanket need be put on, just enough to stop the seepage for a few days. The wheeling runs should be left in position, and, as soon as seepage again manifests itself, work should be resumed until the flow is once more stopped. In this way a force of fifteen to twenty men may be kept nearly constantly employed working from slough to slough.

It is usually the case, when a slough occurs and an inexperienced man tries to correct it, that he will endeavor to restore the lost cross-section with earth or sacks. This does no good, but rather tends to augment the trouble, because the slough is thereby rendered more difficult to drain, and at the same time that much more weight is put on the semi-fluid mass to squash it out, which invariably pulls with it some of the remaining good embankment. He does this because he does not understand what produces the slough. He does not know that it is caused by too free leakage through the embankment and inefficient land-side drainage.

The writer received his first lesson in treating sloughs by observing men at work about a fleet of coal barges. If a barge starts a seam leak, it is impracticable to dig away the coal to get at it. It is equally impracticable to detect the leak by feeling along the outer or water side of the barge, as the inflow is too light to be detected by the hand, and then, again, as a loaded barge draws

from 8 to 9 feet of water, it would oftentimes be impossible to reach the leak by hand. But the coal barge man has a supply of coarse sawdust, and by means of a long handle, to which it is attached, lowers a cup of sawdust in the water within close proximity to the leak, shakes it gently, just next to the barge, and, as the sawdust floats out of the cup, some of it is drawn into the crack and becomes lodged; it very shortly gets wet and swells, and the leak is choked. The same principle applies to stopping sloughs.

SINKING.

Sinking embankment is treacherous and requires the most careful attention and the exercise of good judgment in its treatment to prevent disaster. It is treacherous because its action is sudden and not always attended with premonitory signs, and good judgment must be exercised in treating it, lest the remedial measures prove destructive. A troublesome feature which attends the care of a sinking levee is that it is invariably situated in an ill-drained swamp, which soon fills up with seepage or rainwater, and earth with which to repair it is not immediately accessible, having generally to be transported a long distance on barges. At the present time there are only two lengths of sinking levee in the Fourth District. One of them, which covers about 2000 lineal feet, is at Kempe in the Lower Tensas District, and the other, which is a small affair about 50 feet long, is at Point Manoir in the Atchafalaya District.

Several sinking levees, of greater lengths and attended by subsidence of greater extent than the two levees just named, have been experienced in the past, but after much work they were made secure. The most aggravated cases of sinking seem to have a limit of subsidence, and it is only a question of continuing to pile on earth to secure a substantial embankment. The levees at Kempe and at Point Manoir should therefore be made secure in time.

A levee sinks because it is built on a foundation composed of quicksand or some other equally soft or semi-liquid material, the power of which to sustain weight is governed by the degree of moisture contained at the time the weight of the embankment is put on. It has sometimes occurred that the sustaining power has, during construction, been sufficient to support the embankment, and no movement has taken place until some later date, when the strength of the foundation has become impaired by being excessively wetted.

It has been the general experience, however, that all aggravated cases of sinking levee have been attended by considerable subsidence during construction.

As the weight of the embankment is the direct cause of the sinking, care must be observed not to add, during a flood, more earth than is actually necessary to hold the water. As the embankment subsides, the very lightest possible addition should be made to maintain an elevation several feet above the water surface and the narrowest width of cross-section that will resist seepage. This will entail almost continuous work of small amount rather than a large amount at intervals. It must not be forgotten that if a large amount of earth should be added in a short space of time, the rate of sinking will be accelerated, and the addition will do more harm than good.

Sinking embankment seldom subsides uniformly. Parts of it sink faster than others, causing the levee to crack longitudinally. There is usually one large crack along the crown of the levee, though sometimes other but smaller parallel cracks occur. Care must be taken to keep the water excluded from all or as many of the cracks as possible, particularly the largest one. As soon as water enters a crack, hydrostatic pressure is exerted on the section of embankment in the rear of the crack, and the remaining embankment in front of the crack is rendered valueless as a factor of strength in resisting the pressure of the river. For this reason the addition which is made to keep the top of the levee above the water surface should be placed as far as practicable to the water side of the crack. Lateral cracks which would let the water into the longitudinal cracks must be guarded against and immediately stopped if any occur. If, as is somewhat common, there is seepage through a sinking embankment, prompt measures must be taken to remove the seepage water in the manner described for treating sloughs. As much depends upon keeping the levee dry, it is advisable to spread tarpaulins on the entire sinking levee or at least cover the large cracks while rain is falling, to prevent wetting and to exclude rainwater from the cracks.

A sinking levee may be compared to a sick baby, and requires the same continuous attention and care. As only a small margin of safety exists, a competent force, equipped with ample materials, should be retained at the levee night and day, prepared to care for emergencies at a moment's notice.

WAVE-WASH.

Wave-wash is common on levees exposed to full wave action and not protected by a close growth of grass or some artificial device. It is a much overrated danger, and has been the cause of the needless expenditure of large sums of money in the past.

Wave-wash is misleading in its appearance; in nearly every instance its worst feature is visible, but the inexperienced invariably conceive the idea that the vertical face made by the wash extends to the base of the levee and that the cross-section of the levee has been so much reduced as to seriously endanger the embankment. As a matter of fact the deposed soil settles into position just under the water surface and the reduction of the cross-section is no greater than is apparent above the water surface.

There was a time in the past when the cost of moving earth was comparatively high, and it was less expensive to prevent a part of the levee washing away than to allow it to wash away and afterwards replace it. But this condition no longer exists; under ruling prices for moving earth it is cheaper to restore wave-wash than to prevent it with revetment. Revetment should therefore not be resorted to until the safety of the levee is endangered, which, in the writer's opinion, is not until the crown itself has been attacked. It is accordingly recommended that no steps be taken to arrest wave-wash until the vertical face it cuts has reached the river edge of the crown of the embankment.

When revetment is used, as its service will be but temporary, the most inexpensive structure should be employed. Such a structure consists of posts 3 x 3 inches or 4 x 4 inches, driven into the river slope of the levee and inclining towards the levee at an angle of 15° to 20° from vertical; the upper end of these posts should be rendered immovable by 2 x 6-inch braces connecting them with a short piece 4 x 4 inches or 2 x 6 inches, called an "anchor," driven in the crown of the levee. The posts should be placed not more than 6 feet apart, to give the structure sufficient rigidity to resist the buffeting of the waves. To the outer face of the post must be nailed 1 x 12-inch boards, laid horizontally, care being taken to have the bottom board everywhere throughout its length rest firmly on the slope of the embankment to prevent under wash. It is not usually necessary to maintain the boarding higher than 2 feet above the water surface to provide against destructive overwash. If revetment be placed in the early stages of a flood, the posts should be made long enough to stand such additional plank as the rising river may afterwards necessitate.

EXCESSIVE EROSION AT SALIENT ANGLES.

This is a danger which is not often encountered, and it may be easily provided against; its existence is directly due to the inexperience or inattention to duty of the constructing engineer.

Acute salient angles are rarely put in new levee lines; the

most acute angles put in new levee lines are the re-entering angles. Acute salient angles in the controlling line of levee are usually found at the junction of a new levee with an old one. If such a junction occur behind a sharp point in the line of the river, it will be subjected to excessive velocity of the current. When the river is extraordinarily high, the distance across a point is so much shorter than the length of the channel around the point that the river pours across the point with increased velocity. This excessive flow should be restrained from exerting any influence on the controlling line of levee by leaving the old levee, which the new levee adjoins, undisturbed for several hundred feet from the junction. In building new levees it is a common practice to cut away the old levee, which may be nearby, to secure better building material and at the same time to reduce the length of haul. There is generally no objection to doing this, but in cases of salient angles, which, under the circumstances above related, would be exposed to excessive wash, the practice should be omitted.

If, however, a salient angle should be washing at a dangerous rate, the wash may be arrested by constructing a wing dam to check and divert the current. A suitable and inexpensive wing dam consists of a crib similar to that described under the head of "Leaks," built at an angle of about 45° to the axis of the flow on the upper side of the salient angle. The wing dam should be commenced at a point on the levee about 50 feet above the angle, and extended so far that its outer end reaches to or overlaps the salient.

CUTTING.

Cutting a levee by malicious or insane persons can be prevented only by closely guarding the line while the water is near enough to its top to permit the work of cutting to be done in a short time. Remedial measures are of no avail; preventive measures alone must be employed.

EQUIPMENT AND ORGANIZATION.

To execute most economically, as the exigencies of the situation demand, any of the various kinds of work which have been described, suitable tools and materials and ample labor under competent direction must be at hand. As has been stated, much waste has resulted in the past from the use of other than the materials best suited because the most suitable materials were not available, and from incompetent direction of the work. In protection work, as in other things, "a stitch in time saves nine." Much expense may often be avoided if a weakness be discovered in its incipiency and promptly corrected.

No high-water protection system can be complete without good transportation and good communication facilities. To make tools and materials readily available, supply depots should be established every five miles along the levee line, and these depots should be connected by telephone service.

Each of these depots should be provided with a house in which to store tools and materials and incidentally to furnish sleeping and eating quarters for watchmen and workmen; each depot should be equipped with two small flatboats to move tools and materials to points where they may be needed.

By the time the river has reached 42 feet at Vicksburg, and, later on, 42 feet at Red River Landing, there should be an inspector in the field having general supervision of the high-water work for about 135 miles of levee line. He should keep constantly moving over the line to instruct his assistants and to see that they properly discharge their duties; he should also keep himself informed as to the materials on hand as well as those which may be required.

Under his direction there should be inspectors having local supervision of the work on 20 miles of the levee line each. These men should inspect every foot of the levee line on their beat at least once in every twenty-four hours. As soon as they arrive on the ground, the embankment should be thoroughly cleared of all weeds and coarse vegetation, and the grass should be mowed close to the surface in order to fully expose the entire surface to the closest scrutiny. At the same time, existing drain ditches near the land base of the levee should be cleared and put in good order. If such ditches do not exist they should be promptly cut. As the river rises, or the amount of protection work increases, the 20-mile beat should be reduced to such a length that the inspector can inspect every foot of it daily, and otherwise give it proper attention and competently direct all necessary work.

Whenever the water in the river gets within 3 feet of the crown of the embankment, a reliable day and night watchman, in addition to the inspector, should be placed on every $2\frac{1}{2}$ miles of the levee line, and the watchmen should be required to constantly patrol their beat during the night as well as during the day. If dangerous places develop, no matter what the height of the river may be, a day and night watchman should be retained at each of such places in addition to the patrol watchman.

OBITUARY.

Charles E. C. Breck.

By Joseph H. Curtis and Channing Howard, a Committee of the Boston Society of Civil Engineers.

[Read before the Society, March 21, 1900.]

Mr. Charles Edward Cushing Breck was born in Milton, May 8, 1834. He was educated in the public schools of the town, and took a supplementary course at the Milton Academy. At the age of twenty-one he engaged in land surveying, in Milton and adjoining towns, with his father, the late Charles Breck.

In 1862 he assisted in forming and enlisted in Company B of the Forty-fifth Regiment, Massachusetts Volunteers. He was first a corporal, afterwards a sergeant, and served creditably until the return of the regiment from service. After his return from the war Mr. Breck engaged in farming and floriculture until 1870, when he formed a partnership with Herbert T. Whitman, as civil engineers and surveyors, under the firm name of Whitman & Breck, which partnership continued until 1885. As a member of the above firm he was very actively engaged in the business of his profession in Boston and suburbs, and in New England in general, in these fifteen years doing a very large amount of work.

During this period the firm did considerable steam railroad engineering, including the construction of the Boston, Revere Beach and Lynn Railroad, which was accomplished in a remarkably short space of time, presenting, as it did, most of the problems of a longer section of railroad; also including the construction of the Winthrop Branch Railroad, the beach railroad from Point of Pines to Point Shirley, work on the Manchester and Keene Railroad, the Harwich and Chatham Railroad, the proposed Boston, Lawrence and Haverhill Railroad and a proposed elevated railroad system for Boston and suburbs. A general engineering and surveying business of considerable magnitude was maintained during these years, many properties of successful land companies around Boston being laid out and developed, notably at Winthrop and on the North Shore.

After dissolving partnership with Mr. Whitman, Mr. Breck continued to practice his profession actively as a civil and landscape engineer. He was engaged in the construction and surveys of many public and private grounds, and served as commissioner for abolition of grade crossings, etc.

During about thirty years of business in Boston Mr. Breck occupied only two different offices,—viz, at 209 Washington street, and at 85 Devonshire street. Mr. Breck lived nearly his whole life in Milton, Mass., and served several years on the School Committee and other committees, but was not generally ambitious to hold public office.

In 1894 Mr. Breck suffered from an attack of the grippe, and never fully recovered his health. His death, from apoplexy, occurred January 29, 1899.

Mr. Breck was married, in 1857, to Mary S. Stone, of Belmont, who, with three daughters, survives him. He was a member of the Boston Society of Civil Engineers, of the Boston Veteran Firemen's Association, Macedonian Lodge, F. and A. M., of Milton, and Huntington F. Wolcott Post 102, G. A. R., of Milton.

Mr. Breck was a most companionable and genial gentleman, always ready to oblige others, even at a sacrifice of his own time and interests, and his genial presence will be much missed and mourned by all his professional and other associates.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

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SHOP AND MILL INSPECTORS AND THEIR WORK.

BY W. O. HENDERER, MEMBER OF CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, September 11, 1900.*]

MANY years ago certain truths were expressed by a noted public speaker from which there originated the famous motto, "Eternal vigilance is the price of liberty." By changing one word, and making it read "Eternal vigilance is the price of safety," the motto is rendered no less true and trite, for in this world of ours every man must be vigilant and alive to his own interests to succeed. How many men when buying any article or commodity would feel that they were secure in their purchase if they did not, either themselves or through an agent, assure themselves that they were to get what they paid for?

Watch the careful man when he buys a pair of shoes, for instance. He first decides just what he wants, then he goes to his dealer and states his wishes. The shoes are brought forth; he looks them over, and if they are good shoes and of the quality he desires he accepts and pays for them. In his dealings with the shoe man, then, his procedure covers two things,—specification and inspection.

So it is when a man or a corporation buys a bridge, a building or any structure containing iron or steel. The careful man or corporation is vigilant to his own interests and safety in assuring himself or itself that every detail is constructed just as it should be, and that the materials are of the quality he desires and pays

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for. To this end plans showing just what is wanted and specifications setting forth in detail the method of construction and the quality of the materials and workmanships are prepared. This is the specification part of the dealings. Then, when the structure is being built, the purchaser watches it, or causes it to be watched, to see that all the details and conditions of his plans and specifications are met and complied with. This is the inspection part of the work.

But in the case of iron or steel structures no cursory examination can truly determine whether the material and workmanship is all as it should be. No scrutiny of a finished piece of iron or steel can discover whether or not it is free from imperfections in its composition, and from abuse in the treatment it has received during the various processes in the manufacture of the finished parts of the structure that may seriously and even fatally affect its strength. To be sure that he is getting what he is paying for the buyer must have means of knowing that the raw materials are of good quality; that the metal when rolled contains no harmful ingredients in dangerous quantity; that the material is properly handled, straightened and finished; that the various processes incident to its manufacture into bridge or other structural parts are all properly and conscientiously done; that the parts when finished are all of proper size; that they are painted and treated as they should be; in short, he must, either himself or by a representative working in his interest, follow the progress of the material from the ore to the finished structure. Then, and then only, can he be reasonably positive that his structure is what he desires and pays for.

Such careful attention to details requires that some one be at mills at all times when material is being rolled for the work in hand to conduct the tests of all the material produced, and to measure and carefully examine the bars as they are finished. It requires that some one be at the shops during the manufacture of the parts of the proposed structure from the material received from the mills to see that all the details of the treatment it receives are in accordance with the specifications, and that the finished parts all comply with the requirements as to size and quality of workmanship.

Few purchasers can look after such things personally. They have other things to attend to. Engineers and architects in charge of structures have all they can do to superintend the other parts of the work in hand. The matter of the inspection of the materials entering into them is a detail that they must intrust to an assistant, and so men expert in this particular sort of superintendence have become useful and have found their places among the arts. The

inspector makes it his business to fully understand all the various processes and their results, and to look after his client's interests in all respects.

There was a time when one man could comfortably attend to such duties himself, and personally follow the progress of the material in all its various processes. The shops and mills at which iron was manufactured and where the finished parts of structures were produced were often one and the same, or, if not, the processes followed each other in such rotation that one man could get from mill to shop and keep proper consecutive track of the work. But the industry has of late years grown to such enormous proportions and has extended over such a large area that it is impossible for one man to properly inspect the work in all its stages. Bridge companies now have a number of mills from which to order the material necessary for their work. They are likely to have plates from one mill, beams and channels from another and other shapes from still a third; and the mills are often great distances apart. Frequently, too, the shop is at work on some portions of a contract while the mills are still furnishing materials. It is manifestly out of the question for any one man to thoroughly inspect work at all these places at one time. He must have assistance in some way.

Men who have become expert and experienced in this sort of work have made inspection their particular business, performing this service at a compensation based on the tonnage in the work, instead of entering the service of the engineer or architect in charge at a salary. Such men, as they found it impossible to economically perform their duties personally on account of the excessive expenses of traveling about, adopted the method of reciprocating among themselves, an inspector in Pittsburg undertaking to do the mill inspection on one piece of work for another located in Philadelphia, while the latter attended to shop inspection at shops in his vicinity for the former. Naturally, from such alliances among inspectors, there has resulted the formation of inspection bureaus or companies. Such companies employ men permanently at the various mills and shops, and maintain extensive general offices, at which the clerical work of copying and forwarding reports of tests, progress of work, etc., is performed. By securing large quantities of inspection work they are able to keep good men at all the localities necessary, maintaining a perfect system of effective inspection and giving their clients regular reports of the quality of material and workmanship and the progress of the work, and information as to tests, shipments, etc., which, when completed, comprises an accurate record of the structure in question and surety that it is built as it should be.

Such a company, to be effective and to economically perform good service, requires the most careful organization among its corps of inspectors and clerks. Detailed systems for the handling of such work have been adopted by some companies as the result of much study and experience, and the inspection of various classes of work for clients in all parts of this country and abroad, done at mills and shops in all the centers of manufacture, is performed with the machine-like regularity and uniformity which alone is the safeguard against mistakes, lost records and careless work.

The following brief description of the methods adopted by the inspection department of the Osborn Engineering Company, of Cleveland, Ohio, one of the principal inspection bureaus of this country, will illustrate the care taken to give all work the closest attention, to keep track of its employes and to insure the best results to its clients.

When the contract for a bridge or for any other steel or iron structure is let the inspecting company and the contracting bridge company are mutually notified. The former is supplied with a copy of the strain sheet and general plans and specifications. These are first examined at the inspecting company's general office, and any necessary notes made of special features, and then sent, with instruction slip A attached, to their inspector located at the contractors' shops. When the bridge company places its orders for material with the various mills copies of these orders are sent to the inspecting bureau, where they are copied in duplicate on the blanks C, one copy of which is sent, with instruction slip B attached, to the inspectors located at the various mills where the material is to be rolled. The weights of the various items of material ordered are estimated and entered in the other copy, which is retained at headquarters for future reference.

Each mill inspector first carefully compares his copy of form C with the mill order book, to see that no changes or mistakes have been made in ordering. As fast as the steel is manufactured test specimens are taken by the mill inspectors and the necessary tests are made, the report of tests on each separate blow or melt of steel being sent to headquarters, together with data from the mill chemist's certified report of chemical analysis on the inspector's test slip D. Drillings are also taken, when required or deemed advisable, from the test pieces and sent to headquarters, where check analyses are made in order to test the accuracy of the mill chemist. The test slips D are collected at the general office and copied on the test report blanks E, which, after press-copying, are sent to the engineer or architect. While the material is being

rolled into the shapes ordered the inspector is constantly on hand, and from time to time he calipers and measures the pieces to see that they are of the requisite size and thickness. He sees that the bars are properly straightened and cared for while cooling, and that they show no flaws or ragged edges. As fast as each bar is inspected and found satisfactory he strikes into it a distinguishing mark of the inspecting bureau furnished him from the general office, which signifies that the piece has satisfactorily passed his examination and is composed of material the tests of which have been satisfactory. The stamp he uses, besides the distinguishing mark of the inspecting company, bears a number, and this number is recorded in the general office against his name. He keeps this stamp closely by him at all times, so that there can never be any question as to who performed the inspection on any piece of material. He keeps his general office informed regarding the pieces he has inspected from day to day on any one piece of work by means of the report F. As fast as the material is shipped from the mill he forwards to the general office, after he has checked them, the tissue copies of invoices furnished him by the mill. There the items and weights are checked against those on his report F and against the copy of form C retained at headquarters. The invoices are then copied on the blank G, which is sent to the engineer or architect after press-copying.

Thus the engineer or architect in charge of the work is kept reliably informed just what material has been rolled and shipped, and he knows exactly what the results of all the tests performed on the material have been and what powers of resistance it can be expected to develop. He is protected from any fictitious claims of a delinquent bridge company of delay at the mills. The inspecting bureau has detailed records of the dates on which inspection was performed on any lot of material, and is protected against fictitious claims of delay in the inspection of material at the mill.

As soon as the material begins to arrive at the contractor's shop the shop inspector located there begins making regular weekly reports on the work in hand to his general office. He has, in the meantime, received from the bridge company a full set of the working drawings of the structure. He has carefully checked them against the general plans received at the outset, and has called attention to and had corrected any errors in them or differences between them and the general plans furnished him as his guide. He has also made a careful estimate of the weights of the various finished parts, and a list of all the parts that will be required according to the contract.

It is his duty to be constantly on hand about the shop during the progress of the work, watching the various processes and seeing that everything is done according to the specifications that have been furnished him. He sees that only material bearing the mill inspector's stamp is used, and that it has arrived from the mills in good condition. By watching the processes thus closely he is not only able to detect faulty work which would be covered up when the piece is finished, but he can often save both the bridge company and his employers considerable time and expense by noting mistakes early, while they may still be corrected readily and at little cost. When a piece is finished he makes careful final examination of it, comparing all dimensions with the plans, testing the riveting, etc. It is then painted under his superintendence, and he stamps in the piece, in a conspicuous position, a similar distinguishing mark to that used by the mill inspector to indicate that the shop work has all been properly done and that the piece is as it should be in every respect.

The shop inspector's weekly reports come to the general office in three forms, H, I, and J being respectively his report of material received from the various mills, of the work performed on the structure in the shop and of finished pieces shipped from the shop to their destination during the week. Form H is first checked against form G, and then the three forms are press-copied and sent to the engineer or architect. The method of reporting the condition of the various members of a structure from week to week on form I may require more detailed explanation. The first column, headed "required," shows the number of pieces of a particular mark required. The number in this column remains constant from beginning to end. The other columns show what stage in the process of manufacture each piece has reached each week. Thus in a bridge there may be four end posts required marked aB. The figure 4 would then appear in each report in the first column. One week there might be a 4 in the third column, a 4 in the fifth and a 2 in the next to last, showing that all were assembled, all riveted and two finished awaiting shipment. When the same figure appears in the last column as in the first all the pieces of that kind have been shipped, and when all the pieces required for the work are shown in the last column the material has all been finished and is on its way to its destination.

For every shipment of material copies of the shipping bills, giving the itemized scale weights of the material on each car, are furnished the inspector by the bridge company. He first makes a note of these items and weights, checking them against his list of

parts required to complete the work and the estimated weights he has. He then sends the bills to the general office, where they are copied on form K, which, after press-copying, is sent to the engineer or architect. Reports of tests of full sized eye-bars for bridges are made out on the blank L, press-copied and sent to the engineer. Form M is similarly used for reporting results of tests of cast iron.

When a job is finished a final report is sent to the engineer or architect, stating briefly the work that has been done and noting any unusual features that have developed during the inspection of the material or cases where material was rejected. This report usually includes a summarized statement of the weights of the finished parts, comparing the estimated with the actual scale weights to show whether the various parts have been accurately proportioned in accordance with the drawings, and also a statement of the shipments made, giving dates of shipment, car numbers and initials and weights.

The engineer or architect then has a complete record of the material used on his work, the dates on which the shipments were made from mills to shop and complete records of its progress through the shop and of the shipments from the shop to the building site. With the exception of the slips and form D, all the reports and blanks used are uniformly of letter size and printed on thin paper. They are thus in the best possible shape for filing, and do not make an unnecessarily bulky package. The final report embodies all the points necessary for ordinary cases of future reference. The inspecting company has not only duplicates of all these documents carefully preserved, but all the detailed information of all kinds relating to the work are carefully filed with the copies of reports, correspondence, etc., and stored safely away, thus forming an additional safeguard against loss of records. If at any time in the future information should be wanted concerning the work, if repairs are to be made, or if any question arises as to the strength of the structure, the inspecting bureau can furnish the information if necessary.

One other of this company's many forms may be interesting. Form N is a blank form of diary furnished to all its employes, wherever located. The employes are required to keep thereon a concise diary of their doings and movements, and note the time spent and expenses chargeable on each piece of work. At the end of each period these are sent to the general office, where they are checked over and the time and expenses of each man entered against each job. The company thus has a pretty good check on

each man as to whether or not he is attending to his duty and spending proper time on each piece of work allotted to him.

The employment of competent inspecting bureaus becomes more and more general as the iron and steel industry increases in volume and competition between the manufacturers grows keener. Men are realizing more and more forcibly the necessity for such services in order to insure good results. The day when people thought that because a bridge was built of iron it would stand indefinitely and support any loads that might be imposed is past and gone. Men are finding that there are good and bad iron and steel, and that there is so great a difference between them—often the difference between success and failure, between a strong, stiff and durable structure and an accident costing human life—that it pays to spend the small added cost to insure the use of the good material and to detect and exclude the bad. Nearly all the best structures built to-day are manufactured under the watchful eyes of inspectors employed to see that the provisions of the specifications are strictly followed.

But, unfortunately, this class comprises by no means all the structures built. There are great quantities of iron and steel structural material produced and made into bridges, buildings and other structures on which human life depends that are not so inspected, and concerning which the purchasers have no assurance as to their strength or durability because they have no knowledge of the quality of the material or of the treatment it has received during its manufacture. Thousands of tons of steel are annually manufactured and sold to people who have no way of knowing anything about its quality. Hundreds of bridges and buildings are built every year out of such material, and no one can tell whether or not they will actually stand the strains they are intended to stand. Is the general public to blame when it assumes that such a structure is capable of successfully withstanding the loads and shocks it is called on to resist? Can a man do otherwise when he enters a building or crosses a bridge than place confidence in the care and thoroughness with which its architect or engineer has attended to all the details of its construction? Accidents happen, much more frequently than they should, that are traceable to bad material or workmanship; generally both. If the structure that collapsed had been inspected by competent men such accidents would not have occurred. There is yet to be recorded a single case where a structure properly inspected by inspectors who know their business and do it honestly has failed under the loads it was designed to carry, while, on the other hand, there are many engineers and architects

who can testify to important saving of time and money through the employment of competent inspectors.

It is remarkable that so many fail to see that specification and inspection must always go hand in hand; that neither can confer the benefits it should without the other. Most people realize that if no specifications are stated to indicate the nature and quality of the structure desired the manufacturer cannot be blamed if the structure does not meet the expectations of the purchaser. But often little thought is given to the second part of the purchaser's duty, that of inspection. It is not recognized as a duty owed by every purchaser for his own protection and safety, and to secure benefits from a carefully compiled specification. When the millennium is reached, when it may be reasonably expected that every man's work will be perfect and each one's labor as valuable as that of his fellows, then there will be no difference between good and bad, no possibility of errors or mistakes or dishonesty. When that time arrives there will be no further use for either specifications or inspection, and many a busy man will lose his job. But until that time there will be varying grades in the quality of materials and workmanship, and the necessity for specifying the grade desired on any piece of work will remain. And just so long as there is any cause or reason for specifications, just so long will the inspector be needed to see that the specifications are carried out.

There are various reasons advanced why such inspection service is not employed. Most of them may be classified under the four classes discussed below.

First. Some believe that by placing their work with the best-known bridge companies they are so sure of satisfactory results that no check on the quality of the work turned out is necessary, and that by availing themselves of such a check they are casting unpleasant reflections on the honesty of the bridge company. This is far from a correct view of the case. It is not a question of the integrity of the bridge company or of its management; they may have the best of intentions. But what of the many men through whose hands or under whose eyes the tons of material must pass in its progress from the ore to the finished structure, each one of whom leaves upon it, for better or worse, the results of his work. Each man will look to his own personal interests first. It matters not to him if the material suffers, so long as he can save himself from the consequences of the discovery of his bad work. Besides, it is human nature for a man to underrate an error made by himself. His judgment is warped by his financial interest, and he is apt to think "it is good enough." Thus when a man makes a mistake or

botches a piece of work he is tempted to hide his error in order that his reputation with his foreman may not suffer. He knows that each error made and discovered lowers his value in his employer's estimation. Frequently employes are paid by the piece or ton, the workman then becoming practically a sub-contractor with no interest in the work beyond doing it well enough to get his pay for it. His interest lies in doing a large amount of work; in the production of quantity even at the expense of quality.

Foremen, and even superintendents, will frequently pass flaws and errors that their reputation for executive ability may be maintained. A manufacturing firm looks to its superintendent for results. Time taken to correct mistakes or replace faulty material means decrease of output, and if the output decreases cost increases and the superintendent must explain. So the work is hurried through the shop with speed of completion the principal end in view, and if the foreman or his superintendent notices a defect he is tempted to let it pass for the sake of keeping up the rate of output and saving the expense and time of correcting it.

It is often easy in walking through a bridge shop to tell at a glance which of the various pieces of work in progress are in an inspector's care and which are not. The difference is often apparent to a casual observer. Some bridge companies make it a rule to mark plainly on all their working drawings whether the work is to be inspected or not, and by whom. In this way the workmen have the best of means of estimating the chances of bad work passing unnoticed. The excuse is sometimes made by a shop foreman when a blunder or careless workmanship is brought to his attention by an inspector, "I was not told that this piece of work was to pass inspection."

Some shops maintain on their pay rolls an inspector whose duty it is to examine the work as it comes from the shop and report errors. His duty is performed when the work is finished; he has no jurisdiction in the shop while it is going on. Errors committed and covered up are beyond his detection, and he assumes that they do not exist. But even as regards the errors that may be discovered after a piece is finished, it is human nature for such a man to consult his own interests first and to perform his work in such a manner as best to serve the interests of the people to whom he looks for his pay. When he discovers a mistake in the fitting together of pieces, rivet holes left out of joints, or such like errors, he will report them, because he knows it will cost his employers much more to correct them in the field when they erect the structure than at the shop before the material is shipped to its destination. But he

will be indulgent in such matters as loose rivets, buckled web plates, unannealed forged members, careless painting and the details of construction that may be either good or bad without of a certainty causing his employers trouble later. He casts his lot in with the rest and risks the results, and that such risks are run let accidents on record bear testimony.

Such an inspector is generally some man taken from the shop; some good mechanic who can read a drawing and make an accurate measurement. He is paid little if any more than the men who are doing the work he is called upon to examine, and he draws his pay from the same window and standing in the same line with his fellows. He probably belongs to the same labor union, and is closely associated at all times with the very men who are laying out the work, punching the holes and driving the rivets. It would not be good policy for him to be the cause of too frequent scoring of such men. It might be dangerous for him to be the cause of their discharge.

As to reflections on the honesty of a bridge company cast by the employment of expert inspectors by the architect or engineer, no company honestly trying to do good work has such a feeling. If the inspector knows his business he will not interfere with the men at their work, nor will he cause the company unnecessary trouble in any way. He will be quick to detect errors and see to their correction; often his experience will be of material benefit to the foreman in suggesting the best method of making the correction. The inspector relieves the men from many cares in the performance of their duties, and the bridge company that has nothing to fear from the inspector will welcome him to the shop because he helps them to see that their work is done in the best possible manner and to keep up their standard of perfection in the structures they manufacture.

A few years ago a bridge was built, shipped to its destination by the bridge company and nearly erected before it was discovered that certain important parts necessary to complete it had been overlooked; had never been made in fact. It was during the freshet season, and to save the bridge from being washed away temporary members were devised on the ground and the span fortunately swung before the falsework went out. When the missing parts arrived new falsework had to be built, the span jacked up and disconnected and the new members inserted. Such blunders as this cost money. An inspector who knows his business and diligently attends to it can be the means of avoiding such blunders, and not only of saving his employers time and trouble, but of saving the bridge company from the expensive results of errors.

Second. Some think that the extra cost of inspection adds too much to the cost of the work. They prefer to pay the bridge company its price and run the risk of getting a poor job in return, rather than pay a slight excess to an inspecting firm and have assurance that they are getting good work. They willingly pay a liberal premium in the stock market for bonds of good repute, rather than buy others for less money. And yet is it not cheaper to pay $102 for an article known to be worth $100 than to pay $100 for an article that may not be worth $75? The cost of inspection, by competent experts who make it their duty to watch every detail of the manufacture and check all the plans to see that everything has been done as the architect or engineer intended it should be done, should not exceed 2 per cent. of the total cost of the steel work. Is such a percentage a high rate of premium to pay for the sake of security?

Not only is good inspection worth what it costs to the owner of a structure on account of the security he is warranted in feeling as to its efficiency, but it is a duty owed by every corporation owning structures on which human life depends to take every possible precaution to secure the safety of such structures. It is a good thing for a railroad manager to have inspectors' reports on file concerning his bridges. In case of accident to any bridge, and the often resulting damage suits, one of the first questions asked will be, "Did you have your work inspected, and by whom was the inspection performed?" Several recent suits resulting from accidents to bridges and buildings have developed the fact that no competent inspecting bureau had been employed during the construction, and the testimony has in every case reflected very unpleasantly on the carelessness or gross neglect of the engineer or architect.

Not long ago, in the construction of a railroad, a bridge was required across a certain stream. The railroad company had faith in the bridge company to whom the work was let, and saved the extra cost of inspection. That bridge collapsed within three months after its completion. Subsequent examination showed that not only was the work built at the very lowest limit of safety as regards design, but the material was dangerously high in phosphorus. Careless shop work was admitted, resulting in the punching of clover-leaf rivet holes; and, to crown all, a mistake in marking the pieces had resulted in the interchange of members, a light one being placed where the strain sheet called for a much heavier one and *vice versa*. That accident cost the lives of three men, to say nothing of delays and expense in replacing the structure. Yet

the railroad company justly felt itself lucky, for an excursion train had passed over the bridge but a short time before. It is remarkable, but not at all surprising when the truth is known, what a large proportion of the accidents occur to new structures.

Third. A common claim by the bridge company to the architect or engineer, to influence him against the employment of an inspector, is that there will result serious delay in the completion of the work, owing to the time required for the "perfunctory" duties of the inspector. Extraordinary claims along this line are sometimes made on the part of a bridge company after work is completed, and the inspector is called upon to explain why the delay was caused. Such explanation is seldom necessary from a competent bureau, because, in the first place, the regular reports of the bureau will show the rate of progress of each piece through the shops and just where and when and how any delay was caused by any one or by any cause. In general, however, the claim on the part of the bridge company is pertinent, for the bridge company making such claim generally has reasons of its own for making such statements, and it will generally be found that at such shops delays are actually caused by the inspector on account of the time required to replace faulty material or workmanship which he rejects, and which but for his offices would be incorporated into the work to its great detriment.

Such delays are aggravating no doubt, especially when it is important that the work be finished in the shortest possible time. But it is obviously unjust to blame the delays to the inspector. The delay may mean considerable loss to the purchaser, but he can far better afford such loss than risk the consequences of faulty material or workmanship. And in any case where time is of great importance and a limit of time is agreed to by the bridge company for the completion of the work, any delay of this kind is directly chargeable to the company that undertook to furnish the materials and perform the work according to the prescribed standard within the prescribed time. It is certainly not to the inspector's interest to delay the completion of the work. He is paid for his services by the ton, and the sooner the work is finished the greater will be his profit.

Fourth. It is claimed by many that inspection as it is generally conducted is not effective; that the work is performed in so careless and slipshod a manner as to be void of the benefits it is intended to confer, and that money spent for inspection is practically thrown away.

Unfortunately, this has been but too true in the past. Inspectors worked carelessly and without system. Points which should have been detected were overlooked, and much of the work they were supposed to do was not done at all, or was so poorly done as to afford but little protection to the engineer or architect. Even now there are many who are performing their work in this careless way; undertaking to inspect a piece of work for about half what good inspection costs, and then giving the work what attention they can afford for the price and no more.

Mr. J. A. L. Waddell, one of the foremost bridge and structural engineers of this country, has had his own troubles with inspectors, as may be seen from the following extracts from Chapter XXI of his excellent little book, "De Pontibus." That whole chapter is full of interest in this connection, and will well repay careful reading. Mr. Waddell says, "For many years most of the inspection of structural metal work was a sad farce, and in consequence the general public placed but little confidence in inspection, with the result that a large portion of the bridge work of the country was left entirely to the tender mercies of the manufacturers. Latterly, however, owing to the efforts of a few first-class inspecting bureaus, the status of inspection has been somewhat improved, although it is far from being to-day what it ought to be.

"The inspection business has been utterly demoralized in times past, for it was the general custom, and is yet to a certain extent with some inspectors, to take contracts for inspection at whatever figures the purchasers are willing to pay, then handle the work so as not to lose money on the contract, regardless, of course, of the interests of their employers.

"Strange tales concerning inspection come to the ears of engineers, such, for instance, as passing carload after carload of metal work that was not seen by the inspector until after loading for shipment; but such tales need verification, which of course it is nobody's business to give them. In one case in the author's experience the inspector left his work for ten days in charge of one of the bridge company's shipping clerks, without notifying either the author or his direct employers, the inspection bureau, of his contemplated absence. Such actions as this make one entertain doubts sometimes as to whether inspection really pays."

Mr. Waddell evidently believes that inspection by competent bureaus does pay after all, since he is one of the most careful engineers to see that all his work is inspected and that the rigid requirements of his specifications are strictly followed. But he is just as careful in the choice of his inspectors.

There are a few inspecting bureaus who are striving for the improvement of inspection services, through the establishment of carefully devised systems for the thorough handling of the work and the employment of only experienced and thoroughly reliable men. Such companies can and do give the quality of service that makes inspection thoroughly valuable. But they have thus far found themselves seriously handicapped by the many irresponsible inspectors who undertake work at ridiculously low prices without any idea of doing it as it should be done. Engineers and architects are not a little to blame for this state of things, since too many of them fail to consider the inspection service as one having degrees of quality. They have become accustomed to consider that all inspection is the same, and to require that each inspector who makes application for their work shall submit his prices in competition with any one else who may be an applicant, and then employ the man with the lowest price without taking the trouble to properly investigate the comparative facilities or reputations of the applicants.

It cannot be expected that the best results of inspection will be gained by crowding the price for such services down to the lowest possible figure. There is a limit below which good inspection cannot be performed. The only way in which an engineer can get the full benefit that inspection can confer is to determine at the outset to pay a fair price for that service, and then, before appointing an inspecting firm, to look carefully into the reputations of the different inspecting companies available by references to other engineers and to pieces of work that have been inspected by them.

Thorough and complete inspection of iron and steel structural material should generally be worth one dollar per net ton of shop shipping weights. At times and under especially favorable conditions as regards the location of a bureau's employes, it can be done for less. On some small jobs it may be more, but there is in general a chance for the inspector to make a fair living at that average price. Such inspection should include the careful comparison and checking of working plans and complete supervision and tests by thoroughly experienced, expert and reliable men throughout the manufacture of the material from the time it is first produced until it is shipped from the shop.

The most experienced engineers and architects already realize that only first-class inspection is valuable. These are taking pains to see that only first-class men are employed by them, and at a fair price. Inspection bureaus who enjoy the patronage of such men are doing all their work the best they know how, and are fondly

hoping for the dawn of the day when the general public will recognize the value of the efficient service so rendered.

Good and thorough inspection can be had, but not at the low prices at which so many seem to think it should be done. If complete inspection, as above defined, is worth one dollar per ton, it cannot be expected that the man who refuses to pay that price will get such inspection.

Much of the success or failure of inspection depends on the individual ability and character of the inspector. Good inspectors are not easy to find, and when found they are worth more than the cheap bureaus can afford to pay them. A successful inspector must have a rare combination of good qualities. He must be a practical man, with long training in mills and shops. He must thoroughly understand all the details of the various processes employed, and what are the various faults that are liable to result from each process. He must so well understand these faults as to be able to detect them at once, and he must be so well informed as to know how best to correct them in the most practical manner, and when correction is not possible. But experience in mill and shop practice alone will not suffice. He must also understand enough of structural engineering to recognize the relative advantages of different details and designs. He must be able to figure out the strength of the various connections and parts, and have accurate judgment to determine just what effect a loose rivet here or a bad fit there may have in the resulting structure. He must be quick to think and act, for he is the umpire and his decisions must be prompt and fair if they are to be respected. He must, withal, be a good deal of a diplomat. The inspector who cannot deal with each mill and shop foreman in the way to best command his respect and secure his co-operation will never make a success. And, above all, he must be a man of sterling character, straightforward, upright and honest. His is a position of no slight trust, and he must prove himself at all times truly worthy of that trust.

The inspector's life is not all sunshine. He has many a disagreeable duty, and unless he has the necessary judgment and diplomacy there will be much friction between him and the men in charge of the mills and shops where his work is located. But a good, sensible man, with the qualities of a good inspector, will gain his points without engendering bad feeling; will get over the rough places tactfully, and do his work quietly and unostentatiously, but effectively. Some day the public will appreciate how important his work is, and then the inspector and the inspection business will receive the respect they deserve.

THE OSBORN ENGINEERING CO. **A** **SHOP MEMORANDUM.**

Job No..

Name..

Specifications..

Contractor..

Report to..

" every..

REMARKS..

B **MILL MEMORANDUM.**

Job No..

Name..

Specifications..

Mill..

REMARKS..

C

No. ....

Sheet No.. ....

Order No. .... Contract No. .... 189.........

To ....

Contractor ....

	Item No.	No. Pcs.	Description.	Section.	Length.		Weight.	REMARKS.
					Ft.	In.		

D

Date .... 190 .., ... Inspector.
Mill ....
Contract ....
Order No ....
Blow or Cast .... Furnace Heat ....
Ingot .... Slab .... Piece ....
Test cut from ....
Dims .... Area ....
Elas. Lim. .... Per □″ ....
Ult. Str. .... Per □″ ....
Elong. in .... Per ct. ....
Red. Dims ....
Red. Area .... Per ct. ....
Fracture ....
Cold Bend ....
Quench Bend ....
Drift Test ....
C .... Ph .... Mn .... Sul .... Si ....
Acc. or Rej. ....
Remarks ....

E

Job No.............................

Report No.........................

Report of Tests of..............................Manufactured by ....

For..............................Order for..............................

Reported to..............................190........

Date of Test						
Blow or Melt						
Furnace Heat						
Test cut from						
Original Dimensions						
Original Area						
Elas. Lim., Actual						
Elas. Lim., lbs. per sq. in.						
Ult. Str., Actual						
Ult. Str., lbs. per sq. in.						
Elongation in.........inches						
Per cent. Elongation						
Reduced Dimensions						
Reduced Area						
Per cent. Reduction						
Character of Fracture						
Cold Bending Test						
Quench Bending Test						
Drift Test						
Carbon						
Phosphorus						
Manganese						
Sulphur						
Acc. or Rej.						
Remarks						

We certify that the above-described tests were carefully made.

THE OSBORN ENGINEERING CO.

Tested by..............................

By..............................

F

Job No ....

Report No. ....

To ....

The following material has been inspected at ....

on account of .... order for ....

Date of Inspection ....

Purchaser's Order No.	Purchaser's Item No.	Mill Order No.	Heat No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH.		WEIGHT.	REMARKS.
						Feet.	Inches.		

We certify that the above-described material has been carefully inspected.

G

Job No. ....

Shipping Report No. ....

Date of Shipment ....

....

Shipped from ....

Shipped to ....

Car No. .... Cleveland, O. .... 190.......

Purchaser's Order No.	Purchaser's Item No.	Mill Order No.	Heat No.	No. Pieces.	DESCRIPTION AND SIZE.	LENGTH.		WEIGHT.	REMARKS.
						Feet.	Inches.		

H

Job No. ....
Report No. ....

REPORT OF MATERIAL RECEIVED ....189..........

At the Shops of .... On ....

.... For ....

Date of Invoice.	Kind.	CARS.		From.	Weight.
		Initials.	Number.		
				Total Weight of above.	
				Previously reported.	
				Total to date.	

I

Job No. ....
Report No. ....

REPORT ON CONDITION OF WORK ....190..........

At the Shops of .... On ....

.... For ....

Span.	Location in Structure.	NUMBER OF PIECES.									
		Required.	Punches.	Assem.	Reamed.	Riveted.	Faced.	Forged.	Bored.	Finished.	Shipped

J

Job No. ....

Report No. ....

.... 190......

REPORT OF SHIPMENTS

From the Shops of .... On ....

.... For ....

Invoice No.	DATE.		CARS. Initial.	CARS. Number.	DESCRIPTION.	WEIGHT.
					Total Weight of above.	
					Previously reported.	
					Total to date.	

We certify that the above-described material has been carefully inspected.

THE OSBORN ENGINEERING CO.

By .... Inspector.

K

Job No. ....

Shipping Report No ....

Date of Shipment. ....

....

Shipped from ....

Shipped to ....

Car No. .... Cleveland, O. .... 190......

Contract No.	No. Pieces.	DESCRIPTION.	MARK.	WEIGHT.	REMARKS.

We certify that the above-described material has been carefully inspected.

L

Job No. ....

Report No. ....

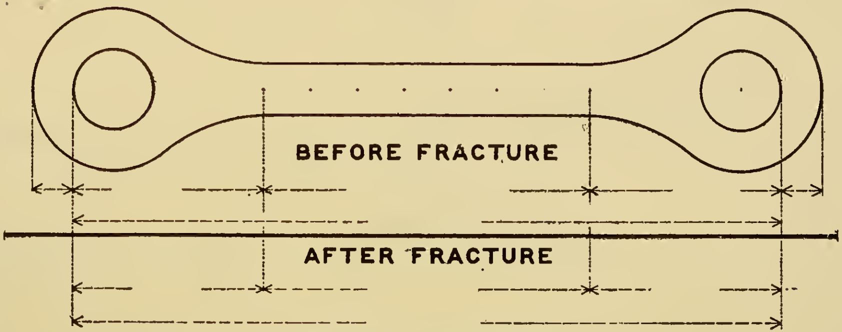
Report of test of .... Manufactured by ....

From Material Rolled by .... For ....

Reported to ....

Date of Test .... Blow or Melt No ....

Head A.	Head B.
Width ....Inches	Width ....Inches
Thickness ....Inches	Thickness ....Inches
Dia. pin hole ....Inches	Dia. pin hole ....Inches
Excess .... per cent.	Excess .... per cent.
Elongated Diameter of pin hole A ....Inches	Elongated Diameter of pin hole B ....Inches



TOTAL ELONGATION

Elongation in .... 12″ spaces

....

....

L (CONTINUED).

Nominal Section.................... Actual Section.................... **ACTUAL AREA**....................

Elastic Limit; Gauge.................... Actual.................... **LBS. PER SQ. IN.**....................

Ult. Strength; Gauge.................... Actual.................... **LBS. PER SQ. IN.**....................

Elongation; in.................... inches.................... = ... **PER CENT.**

Elongation; in.................... feet.................... = ... **PER CENT.**

Fractured Section.................... Area.................... **REDUCTION**.................... **PER CENT.**

Location of fracture.................... from back of Eye....................

Character of fracture....................

Accepted or rejected....................

Remarks....................

....

Specimen test from same blow or melt shows the following results:

Elastic Lim. per sq. in.................... Ult. Str. per sq. in....................

Per cent. Elong. in 8 in.................... Per cent. Reduction....................

Carbon.................... Phos.................... Mang.................... Sul....................

We certify that the above-described test was carefully made.

Tested on.................... machine.

At....................

By....................

THE OSBORN CO., Civil Engineers.

By....................

M

Job No ....
Report No. ....

Report of Tests of Cast Iron Manufactured by ....
For .... Order for ....
Reported to .... 189 ....

Date.	Cast No.	Specified Load.	Section.	C. to C. Bearings.	Breaking Load.	Deflection.	CASTINGS REPRESENTED.	REMARKS.

We certify that the above-described tests were carefully made.

THE OSBORN ENGINEERING CO.

Tested by .... By ....

N

DIARY

Of ....

From .... to ....

Job.	DIARY.	Hours.	Exp.	Job.	DIARY.	Hours.	Exp.
	1st.				5th.		

☞Each employe is to fill out this form, day by day, giving complete description in detail of the kind of work done, at what place and time spent. He is a'so to state in detail what moneys he has expended on this Company's account, and for what purpose. At the end of the period noted hereon this sheet must be turned into the Cleveland office, giving a complete diary and statement of time and expense for the period.

NOTES ON PILE-DRIVING.

By James C. Haugh, Member Louisiana Engineering Society.

[Read before the Society, July 9, 1900.*]

The most satisfactory and reliable pile-driving is where the piles are driven a sufficient depth through a material readily penetrated by the piles and overlying rock or other impenetrable material on which the points of the piles would rest. The sustaining power of the piles would then be equal to strength of the material of the piles.

Piles driven as in Fig. 1 would, according to formulas in common use, support the load of trains and locomotives. The penetration of these piles, driven into quicksand, is little or nothing for a number of blows of a 2200-pound pile hammer dropped 15 to 20 feet, yet the result, after trains began running over such pile bents, was a constant settlement of the piles, doubtless caused by the weight of trains and the vibratory motion given to the piles. Had the material overlying the quicksand been of greater depth and firmer, the vibratory motion might not have been communicated to point of piles and settlement would not have occurred.

Fig. 2 shows the conditions for pile-driving in a "pile trestle crossing" of Lake Pontchartrain. The lengths of the piles varied, in different portions of the 6-mile trestle, from 45 to 70 feet. Piles showed considerable variation in the material in which the piles were driven. The shorter lengths were driven into a hard clay, and the longer lengths through material as shown in Fig. 2. The longer lengths gave a very uniformly soft penetration, and for a number of blows the penetration was as great as 1 foot for a 10 to 15-foot drop of a 3000-pound hammer run by a friction driver and hitting short blows very quickly.

In driving these piles it was observed that if the pile giving this penetration was allowed to stand for a few hours, owing to breakdowns or other causes, it required several blows to start it, but that after it was started the same penetration resulted as before the stoppage.

The quick blows doubtless caused the material through which piles were driven to be displaced, and a cessation of driving allowed the material to resume its normal condition, with the resulting friction around the piles.

Although the trestle has been in use for over fifteen years, none of the piles have settled. Very similar conditions of driving

*Manuscript received August 23, 1900.—Secretary, Ass'n of Eng. Socs.

were met with on the $15\frac{1}{2}$ miles of marsh trestle work, where the length of the piles varied from 25 to 50 feet. The penetration of the 50-foot piles in the marsh was the same as that of the 75-foot piles across the lake. The marsh being about 2 feet above the lake level and the trestle grade being 3 feet lower across the marsh than across the lake, approximately the same penetration in the ground was obtained. No settlement occurred across the marsh trestle.

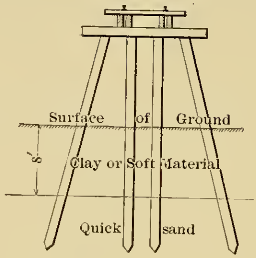


FIG. 1. PILES DRIVEN IN QUICKSAND.

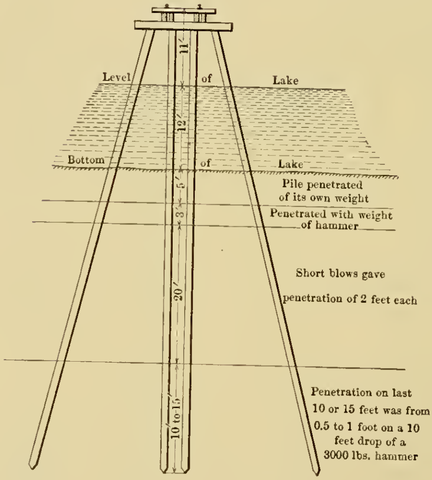


FIG. 2. PILES IN LAKE PONTCHARTRAIN.

The firmer material, where short piles were driven, gave a penetration of 0.20 for a 15 or 20-foot drop of a 3000-pound hammer.

Test showed that pile hammer could be so freely dropped as to give eight or nine-tenths of the same penetration as when line was cut and hammer dropped free of line from a 40-foot height.

Tests showing the sustaining power of piles driven in different portions of the city between the river and the lake would probably

show that shorter lengths of piles than the 70 to 80-foot lengths now being driven to support buildings, heavy machinery, etc., would be sufficient.

The condition of creosoted long-leafed yellow pine piles and creosoted square timber, both of the best quality and close grained, used in the construction of trestle in the lakes and coast water of Louisiana and Mississippi, shows that the lasting quality of the timber is very greatly increased by creosoting, creosoted piles and timber being now sound after eighteen or twenty years' service.

The piles used are round piles, barked and peeled, and having from 1½ to 2½ inches sap wood and about 12 inches heart diameter at large end.

The square timber should preferably have sap angles and surfaces, for larger oil absorption, thus more effectually protecting the "heart wood" from decay.

The piles receive a seasoning treatment lasting from three to six hours, according to size of timber and degree of seasoning before treatment.

The timbers, on being closed in treating cylinders 6 feet diameter and 100 feet long, were saturated for an hour or more with steam from perforated pipes in the cylinders. Then the temperature was run up to from 275° to 290° F., and the vacuum pump was started, when a vacuum of 27 to 28 inches was had. All moisture was considered as removed, and timber seasoned. The creosote oil was pumped into the cylinders and kept at a temperature of from 150° to 170° F. until a pressure on oil of from 80 to 100 pounds showed that the timber was not absorbing any more oil. The time was about from four hours on 6 x 8-inch x 9-foot timber to eight hours on heavier timbers.

The "creosote oil" used is the best dead oil of coal tar, unadulterated, and having a specific gravity of not less than 1.03 at 60° F. The oil must completely liquefy at a temperature of 60° F. and boil at 410° F. or above. The oil must have not less than 50 per cent. of naphthalene.

DISCUSSION.

J. W. Hazlehurst.—In connection with the interesting discussion of this subject I should like to add a few words relating to a personal experience in pile-driving for foundation work under local and normal conditions, and where the bearing value of the pile must be determined entirely from the frictional resistance of the soil acting upon the sides of the pile. Being called upon to design a water supply plant several years since for Algiers. Fifth

District, New Orleans, an item of construction was the foundation for a stand pipe 13 x 100 feet, whose total weight and stresses were found to amount to 600 tons. In order to increase to a safe permissible limit the bearing value of the soil the usual method of piling and grillage was resorted to, and 100 piles, having 12-inch diameter heads, were driven to a depth of 60 feet. The individual piles of this cluster were spaced 2 feet from centers, both longitudinally and laterally. In computing the theoretical ultimate bearing value of each pile the frictional resistance was assumed at one-half ton per linear foot of timber, reduced by a factor of safety of 5, which gave as the safe theoretical bearing of the cluster 600 tons, or a resistance equal to the weight applied. So far as has been observed, no settlement or other distortion has taken place. The individual bearing value, 6 tons, assumed for each of these piles is approximately the same as would have been obtained from the Rankine formula, where the safe bearing value is equal to the area of the head in inches multiplied by 200. Thus, if the head measured 12 inches in diameter the area, 78 square inches, into 200 equals 7.8 tons as the safe theoretical bearing for piles depending entirely upon frictional resistance for support. Some years since, in driving piling in a soft sea marsh, and where the character of the bearing material had been previously determined by water jet borings or soundings, I used this formula in determining the frictional resistance of three-pile bent work in a temporary railway trestle, and from an observation of the loads and slight subsequent settlement I am of the opinion that this formula, when used under like conditions, very nearly represents the true bearing value of piling which has no firm underlying stratum upon which to rest.

W. B. Wright.—I recall the case of a temporary railroad pile trestle one mile long (later filled in) across a piece of bottom land. This trestle was 30 feet high, and this was considered by some engineers as the limit desirable for such structures; higher trestles preferably to be built with short piling and superimposed framed bents of, say, 20 to 25 feet each until the desired height is reached. On the first work, of which I had charge, was built such a trestle 75 feet high and 1000 feet long.

Usually at a bridge site, at every 10 feet, a ½-inch sounding rod was sunk into the ground as far as two or three men could force it. Then piles were billed to extend 10 to 14 feet deeper, and 2 feet above cut-off was allowed for brooming. Piles billed in this manner rarely went below the calculated depth, and usually gave some waste. I remember well, however, one bridge site where the sounding rod discovered 5 feet of gravel with hard bottom, but

the pile driver discovered 6 feet of gravel with a soft stratum below. In this case short piles 10 to 15 feet long, with square points, were driven and doweled, and the regularly billed piles were driven on top, giving invariably good results.

The sounding rod would not always give satisfaction. Among other deep swamps, I remember one which allowed piles to go 150 feet without reaching bottom. Such swamps will not bear a high embankment, but can often be crossed on corduroy composed of trees laid with tops lapping on the center line, on which a light embankment is built. This structure quakes when the train passes over, but gives the best of results in maintenance of way and ease on trains.

Sometimes an ordinary bank across a swamp will stand a long time without settling, or will at last seem to stop settling; but I know of one instance where a 6-foot bank that had stood for thirty years suddenly sank out of sight two minutes after the passage of a passenger train. Piling in this bank, although not giving perfect support, would probably have prevented this accident.

Piles for railroad trestles are usually driven four to a bent, with spans of 12 to 15 feet. One pile is driven vertically under each rail, and the others on the outside, often with a batter of one or more inches per foot, the driver being tilted for this purpose. Over creeks center spans of as much as 24 feet, with heavy stringers untrussed, have been used with special bents of six or eight piles.

At a division yard I once received for construction purposes a lot of cedar piles, some of which, I was astounded to see, were more than 3 feet in diameter. On making inquiries I found that the inspector, an old engineer, had been told by the lumbermen that if he wanted any piles he would have to take all timber just as it was cut, whether large or small. Haste being imperative, he had accepted, and said what could not be driven would have to be used for firewood.

Piles driven in frosty ground, where frost has to be cut out before driving, should have the holes made of sufficient size to give some latitude for straightening up, or they may be driven badly and be hard to spring into place, and may throw the bridge out of line in the spring when the frost goes out of the ground. One must be careful in standing near piles driven in frosty weather. I once saw a splinter 6 feet long split off by the blow of the hammer just graze a man's back and bury itself in the frozen ground, whence it could not be removed. If the contractor fails to properly spring in piles, cap-drift bolts may be sawed off and piles properly resprung.

Some engineers carry their penchant for piles so far as to order them driven in all cases. In some instances this order has been so strict that, especially on side-hill work, piles have been dug out. A foundation on mud sills would seem to be perfectly allowable, at the discretion of the assistant. I have seen cases where an iron shoe, cast with a wrought iron dowel, enabled piles to be driven where otherwise penetration was impossible.

Under a large wharf and warehouse at a seaport town many of the piles were weakened by teredo, or more frequently girdled by a small insect which eats into the pile, diminishing its diameter 1 inch or more per year, until between tides there is nothing left. No difficulty was experienced in driving 80-foot piles outside the warehouse, but inside, in order not to remove the roof, a low pile driver was used and 20-foot lengths were driven down, one on top of another, to the desired depth and braced to the sound piles remaining. With proper bracing this could have been extended later to all the remaining piles, and with proper connections the last 20-foot pieces driven could have been taken up eventually and replaced by new ones over the whole area. Of course, this was in a harbor. In a seaway not even iron screw piles are always able to stand the force of the waves.

There are many ways to protect piles from teredo and insects. At Bay St. Louis they are encircled with vitrified pipe filled in with sand or cement. I have seen piles covered with tar paper, over which thin strips of redwood were nailed, as the teredo does not readily attack this wood. Copper sheets are sometimes used, but they are very expensive. Piles with bark on are much less rapidly attacked than when stripped of bark. In using piles with bark on, where it was accidentally knocked off in places, there was applied a coating of tar mixed with Paris green. I have but little faith in the effective endurance of this preparation.

Piles are not usually driven much closer together than 3 feet centers, for when they are driven closer it is not probable that they will sustain much more, for the whole inclosed space then tends to sink as a solid mass.

On the drainage work here in New Orleans test piles were driven over the whole area of the site of the central electric power station, as also at the sites of the several pumping stations. The results were exhibited to the eye in the form of curves in which the abscissas represent the penetration of the point of the pile below the surface and the ordinates the number of blows of the hammer required to cause one foot of penetration. Test borings were also made at each site, in order to determine the nature of the material in which the piles should be bedded.

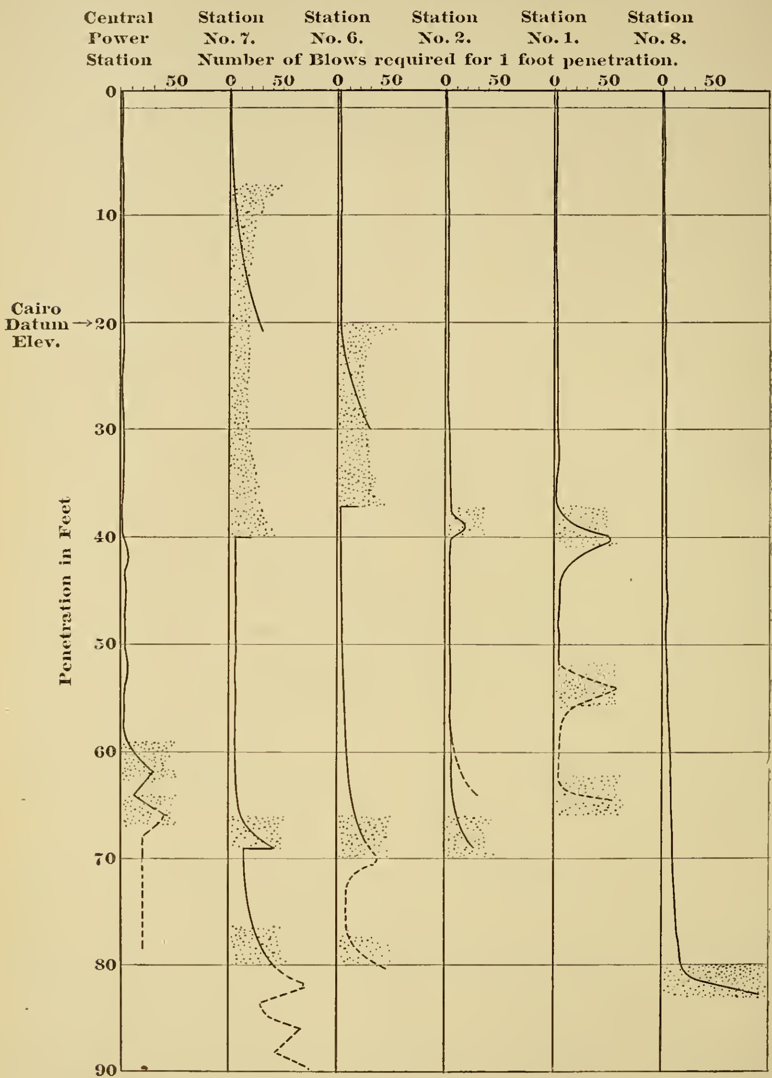
I have prepared a diagram showing a single curve of average results at each of the different sites. Curve No. 1 represents the results at the central station. Here the piles penetrated 35 feet under the static weight of the hammer alone. A satisfactory resistance was encountered in two strata of sand and shells at a depth of 65 to 70 feet below the surface, as shown, and piles were billed long enough to reach the second stratum should the first be penetrated too easily. Two thousand piles were driven, beginning at one side, and the driving did not become noticeably harder on account of the number of piles driven as the work proceeded, but the ground heaved up considerably and necessitated the raising of the plane of cribbing. It is sometimes better to drive from the center outward, but it is often easier and more economical to begin at one side. The ground being very full of old cypress stumps, many piles drove somewhat out of line. Cross-capping below or extra capping alongside was sometimes resorted to in such cases. The piles in the stack foundation were allowed to project 6 feet upward into the masonry, making it a much more stable structure than if set immediately on grillage.

At station No. 7 a sand stratum was met at 10 feet below the surface, giving great resistance. The first test pile was driven for a long time, but failed to pierce through. The second was helped by a small water jet, but it also failed to pierce. Then a larger jet was rigged up, and the lower side of the stratum was found to be at a depth of about 41 feet, showing a thickness of over 30 feet. This would have given a bed of sand of over 20 feet below the foundation of the building. It was not, however, deemed advisable to dispense with piles, as there would be such a head of water against the building on the lake side and the sand, although sea sand, was water bearing and might flow.

In driving the piles the jet was sunk with the pile only to the bottom of the sand stratum, where it was held, and this removed nearly all friction to that depth. Beyond this the piles drove through a second resisting stratum at 70 feet depth, and brought up witn good resistance on a third stratum at a depth of 80 feet. One test pile driven 90 feet indicated still another resistance at that depth. The jet was attached to the side of the pile, and the point seemed to have a slight tendency to follow the jet sidewise in going down.

At station No. 6 a sand stratum was encountered at a depth of about 22 feet. The test piles showed that this stratum could be penetrated by hard driving, but a jet was used later for economy and to secure more uniform and better results. Piles jetted gave

usually good resistance at a depth of 70 feet, as shown. During the excavation work it was seen that not all the test piles had



pierced the sand stratum, but those with knotty ends had broken off some distance from the point; and the new point thus formed reaching the sand, in some instances a second break had occurred. Some of these piles were entirely dug out, the points never having

reached cut-off when the record showed many feet below. Test pile No. 1 at station No. 7 was also dug out, and proved never to have reached cut-off. Some feet above the point was a mass of fiber, resembling worn out rope. This mass was as large as a barrel, and of about the same shape.

At station No. 2 a resistance was met at a depth of about 40 feet, which, however, was safely penetrated, the piles bringing up at 65 and 70 penetration with good resistance.

At station No. 1 the test piles showed resistances at depths of 40, 55 and 65 feet. The first stratum was penetrated with difficulty, the second in but one or two instances. Piles were intended to rest on the second stratum about 35 feet below cut-off. With hard driving, nearly all reached this stratum. In driving test piles the second day two of them refused to penetrate the first stratum, six hundred blows of the hammer seeming to have no effect. I had just read in an engineering paper that piles driven in sand to refusal, if allowed to rest, after dispersal of strains at the point, could be driven further down. It was decided to leave these two piles 20 feet above the ground. Redriven the next day, after about sixty blows to remove friction, they started and went down with unexpected ease. It seems that after the driver has stopped for any reason the piles usually start harder, but, once started, they go down at the previous rate. Piles rested over night are harder to start, but, once started, they also go on down as easily as on the day before. The same proves true of piles rested for a month or more. When an ordinary pile follower is put on the pile seems to go somewhat harder, but this may be due to the cushion formed by an imperfect joint. A broomed head forms a cushion, so as to give false results in calculating sustaining power of pile. The pile head should be cut off afresh and proper record taken.

At station No. 8, in Algiers proper, resistance was discovered at a depth of about 85 feet by the first test pile driven. Then two test piles drove to 130 feet with no bottom. These were 70-foot piles, doweled and followed by 60-foot piles. At one point there was a jump of from four blows per foot to two blows per foot; and although the difference was so very slight, it was still noticeable, and it was suspected that the followers had jumped off. Usually the follower will stand a great deal of driving before failing. Work was stopped and iron rings were sent for; head and point were strongly ringed and doweled. These piles brought up at 85 feet, practically at refusal, showing conclusively that previous results were false. Piles with large points drove harder and gave greater resistance, and sooner than those with slim points.

On the pole line between the central power station and stations Nos. 7 and 6 piles were driven for supporting the poles from Bayou St. John to station No. 6. The sand stratum encountered rose from 14 feet in depth at Bayou St. John to 10 feet at station No. 7, and fell to 22 feet at station No. 6, showing the highest point of the sea beach to be at station No. 7. It is lower toward the lake, and also toward the river. Large quantities of many varieties of sea shells in perfect preservation were found during the excavation for the foundations. These shells, where they were abundant, gave much greater resistance to the piles than the sand alone.

In driving piles for bridges over canals, throughout the first or upper drainage district, a sand stratum was encountered at a depth of about 40 feet which gave sufficient resistance. When this stratum is reached piles bring up almost as suddenly as if they had struck rock. With hard driving it can be pierced as at station No. 1. Piles were billed 40 feet long, and usually gave a little waste. This stratum extends also over the second drainage district on the river side of Metairie Ridge, and supports the piles of all the conduit work, as well as bridges over canals. In removing old piling, to allow the passage of the dredge at bridge sites, a hole is reamed out, into which is introduced a light pole to which two dynamite cartridges are attached. These are fired by electricity, and cut the piles off easily and with certainty.

The system of massing piles under heavy weights was preferred in foundations to that of spacing them uniformly over the whole area, even if the concrete base on strong grillage should act as a monolith. Some engineers prefer to drive all piles to a uniform resistance, decided upon beforehand, no matter at what depth it is encountered, but we drove to the greatest resistance we could get, depending on the average for good results. When foundations are large and act as a monolith, this would seem to be the better rule. Theoretically, if pile-driving over portions of a large foundation became harder, it would be economical to calculate on greater sustaining power and omit a portion of the piling.

The steam hammer, with its low fall and rapid blows, is much to be preferred to the drop hammer, which gives rest between blows and tends to mash the heads. The steam hammer was required on the drainage work, and those used weighed about 9000 pounds, the hammer proper weighing 4500 pounds. The drop measured $3\frac{1}{2}$ feet. It was calculated not to make any pile bear more than 10 tons, and a resistance more than sufficient to support that amount safely was always obtained from average results.

TESTS OF CONCRETE FOR ELASTIC PROPERTIES AND ULTIMATE STRENGTH.

By W. H. Henby.

[Read before the Engineers' Club of St. Louis, June 13, 1900.*]

The use of concrete for a building material is increasing very rapidly; its strength and durability, combined with ease of handling in construction, and cheapness make it a very satisfactory material for use in construction where it has been the practice to use stone or brick masonry.

Compared with its increasing popularity, and the great demand for hydraulic cement during the last few years, there is very little definite information in engineering literature upon its physical properties.

The standardization of the testing of cement, and the testing of a number of cubes and prisms for ultimate compressive strength and elastic deformation, in some of which tests data are given to show what is the most efficient mixture for the given class of materials under the existing conditions, represent the greater part of what has been done and is to be found in print upon this subject. The tests made have been for the determination of the compressive strength of concrete and its compressive modulus of elasticity, and, while these are the physical properties of most interest to users of concrete, some definite information upon the tensile strength and tensile modulus of elasticity may prove to be of more than merely theoretical interest.

For several months the writer has been engaged with Mr. E. C. Dicke, of the class of 1900, Washington University, in a laboratory investigation of the elastic properties and ultimate strength of stone and cinder concretes under both tensile and compressive stresses. These tests were made in the Washington University Testing Laboratory as thesis work.

It is the purpose of this paper to present the results of these tests and some conclusions derived from a consideration of them, and to consider briefly some of the factors entering into the mixing and placing of concrete which affect its efficiency.

In reviewing what has been done in this field of investigation a lack of uniformity of results is encountered, not only between the results of different investigators, but in the results coming from the same source. This lack of uniformity may arise in part from the range in strength of the component parts, and, in any investi-

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gation, should be determined so far as is possible and weighted when evaluating results.

Where stone, crushed to stated sizes, as in this investigation, is a component part of the mix of concrete, incipient fractures in the pieces of stone may greatly reduce the tensile strength of a test-specimen. Such a fracture not only reduces the area of cross-section by the component of the fracture at right angles to that axis of the test-specimen in whose direction the stress is applied, but, by introducing an element of weakness in one part, causes the section to be unsymmetrical and the specimen to fail by a combined tensile and cross-breaking stress. The fact that in this investigation the stone concrete failed at a lower tensile stress than the ultimate tensile stress of the mortar used in making the concrete, and that the stones in the plane of rupture were pulled in two in that plane, shows the stone to be the element of weakness in the concrete when it is subjected to tensile stress.

Besides the range of strength of the component parts, the other principal factors which may cause a difference in the physical properties of any given mix of concrete are: The much-mooted question of consistency; thoroughness of mixing; the compacting of the concrete in place, and the treatment of the test-specimen while it is seasoning. In regard to consistency, the conclusion derived from a careful consideration of the numerous tests made is that the greatest strength is developed when the mix is damp enough for a small amount of moisture to be flushed to the surface under heavy ramming. This consistency is usually designated "dry." A less amount of water than enough to effect this consistency does not insure a coating of all the coarser components with the cement and a weaker product results. A greater amount of water gives the mix sufficient plasticity to prevent the effecting of the desired density, and the broken section shows voids of considerable size and aggregate volume proportional to the excess of water used. From the tests it appears that the decrease in strength due to an excess of water is rather more than proportional to that excess.

The tests show that, other conditions being equal, any increase in density effected by compacting in place by ramming increases very materially both the ultimate compressive and the tensile strength.

In regard to treatment: The specimen made of the right consistency to give greatest strength and allowed to set in the dry air of the laboratory without the protection of damp cloths during the first forty-eight hours had a less ultimate strength and somewhat

TABLE I.

SHOWING THE MODULUS OF ELASTICITY AND ULTIMATE TENSILE STRENGTH OF VARIOUS MIXTURES OF STONE-CONCRETE, MORTAR AND CEMENT; ALSO THE EFFECT OF DENSITY, CONSISTENCY AND TREATMENT ON THE STRENGTH.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Parts of Sand.	Parts of Stone.	Brand of Cement.	Size of Broken Stone in In.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. in.	Consistency.	REMARKS.
8		7	Tension	1	2	4	Lehigh	1½	Air dry		2,000,000	130	Dry	
10		18	"	1	2	4	Medusa	1½	"		2,286,000	75	Excess	Not well compacted.
16		30	"	1	2	4	Lehigh	1½	"	142	2,882,000	198	Dry	
17		30	"	1	2	4	"	1½	"	148	4,727,000	227	"	Very dense specimen.
18		30	"	1	2	4	"	1½	"	142	2,269,000	191	Plastic	
35	64	55	"	1	2	4	"	1½	"	147	4,543,000	149	"	Very solid section.
36	31	90	"	1	2	4	Medusa	1½	"	147	3,500,000	125	Excess	
65	55	96	"	1	2	4	Lehigh	1½	"	146	3,992,000	190	Plastic	
66	56	96	"	1	2	4	"	1½	Air	147	4,760,000	226	"	All stone in section broken.
72	84	8	"	1	2	4	Atlas	1½	"	157	3,720,000	213	"	
67	57	100	"	1	2	4	Lehigh	1½	Air dry	147	5,075,000	209	"	Well-made specimen.
18	1	30	"	1	2	4	Atlas	2	Air	148	3,306,000	192	"	
165	24	120	"	1	2	4	Medusa	1½	Air dry	143	3,473,000	136	Excess	Large voids in section.
166	25	120	"	1	2	4	"	1½	"	144		89	"	" " " "
220	21	90	Compression	1	2	4	Atlas	2	"	140	4,421,000	1,243	Dry	Adhesion poor.
221	24	90	"	1	2	4	"	2	"	144	5,792,000	982	"	" "
222	82	30	Tension	1	2	4	"	1½	Air	153	3,750,000	223	Plastic	Clean break.
223	83	30	"	1	2	4	"	1½	"	150	3,600,000	241	"	
224	85	30	"	1	2	4	"	1½	Water	158	3,550,000	279	"	Very solid section.
225	36	30	Compression	1	2	4	"	1½	Air	160	7,171,000	3,020	"	
226	37	30	"	1	2	4	"	1½	Water	152½	4,625,000	2,610	"	Slightly defective.

TABLE I.—Continued.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Parts of Sand.	Parts of Stone.	Brand of Cement.	Size of Broken Stone in In.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Consistency.	Remarks.
227	18	90	Tension	1	2	4	Atlas	2	Air dry	147		58	Very dry	Water absorbed by stone.
283	11	65	"	1	2	4	"	2	Air	144	3,810,000	143	Plastic	Failed in head.
284	12	65	"	1	2	4	"	2	"	149	3,724,000	102	"	Voids due to excess of water.
286	58	65	"	1	2	4	"	2	Water	150	5,440,000	82	"	" " " " " "
295	8	64	"	1	2	4	"	2	Air	151	7,744,000	252	Dry	Failed in plane of micrometer screws.
315	109	30	"	1	2	4	"	2	"	149	8,360,000	183	"	Failed in shoulder.
316	110	30	"	1	2	4	"	2	"	148½	7,280,000	214	"	" " "
3		14	"	1	2	5	Medusa	1½	Air dry	139	2,000,000	85	Plastic	Not well rammed.
5		18	"	1	2	5	"	1½	"		2,106,000	120	"	Same mix as No. 3.
22		60	"	1	2	5	Atlas	1½	"	144	1,857,000	111	Very dry	Adhesion to stone poor.
25		60	"	1	2	5	"	1½	"	146	3,253,000	128	Dry	
26		60	"	1	2	5	"	1½	"	146	3,023,000	189	"	
30		90	"	1	2	5	Medusa	1½	"	140	3,776,000	142	"	
76	38	9	Compression	1	2	5	Atlas	1½	Air	152	4,930,000	423	Plastic	
78	89	7	Tension	1	2	5	"	1½	"	152	3,968,000	147	"	Voids in broken section due to excess of water.
80	25		Compression	1	2	5	"	2	Air dry	146	3,927,000	726	Very dry	Rammed in mold transversely.
106	14	90	Tension	1	2	5	"	1½	"	144	3,696,000	129	"	
107	15	90	"	1	2	5	"	1½	"	144	3,896,000	93	"	
236	87	30	"	1	2	5	"	1½	Air	145	4,532,000	165	Plastic	Failed in head.
237	88	30	"	1	2	5	"	1½	"	152	4,425,000	242	"	
241	90	30	"	1	2	5	"	1½	Water	155	5,000,000	239	"	Failed very close to the elastic limit.
248	39	32	Compression	1	2	5	"	1½	Air	151	5,055,000	2,097	"	Planes of fracture well defined.
249	40	32	"	1	2	5	"	1½	Water	154½	7,292,000	2,830	"	" " " " "
287	29	63	Tension	1	2	5	"	2	Air	146	4,980,000	154	Dry	Poor adhesion.
288	30	63	"	1	2	5	"	2	"	146	3,744,000	192	"	
91	94	7	"	1	3	6	"	1½	Water	154	3,828,000	115	Plastic	
96	21	30	"	1	3	6	"	2	Air	150	3,810,000	119	Dry	

TABLE I.—Continued.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Composition. Parts of Sand.	Composition. Parts of Stone.	Brand of Cement.	Size of Broken Stone in In.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Consistency.	Remarks.
272	22	60	Compression	1	3	6	Atlas	2	Air		2,886,000	413	Very dry	Rammed in mold transversely.
242	91	30	Tension	1	3	6	"	1½	"	147		130	Plastic	
243	92	30	"	1	3	6	"	1½	"	147	2,427,000	104	"	All stone broken.
244	93	30	"	1	3	6	"	1½	"	148	2,440,000	128	"	Good section.
245	98	30	"	1	3	6	"	1½	"	144	4,496,000	93	"	High modulus elasticity not explained.
250	41	34	Compression	1	3	6	"	1½	"	143	5,104,000	1,310	"	
251	42	39	"	1	3	6	"	1½	"	146	7,520,000	1,733	"	Good test.
252	43	39	"	1	3	6	"	1½	Water	152	6,646,000	2,242	"	" "
253	44	38	"	1	4	8	"	1½	"	143	4,560,000	1,282	"	Well-made specimen.
254	45	38	"	1	4	8	"	1½	Air	139	2,446,000	617	Excess	Voids in section due to excess of water.
255	46	38	"	1	4	8	"	1½	"	138	2,247,000	797	"	
270	99	30	Tension	1	4	8	"	1½	"	143	3,553,000	71	Plastic	
271	100	30	"	1	4	8	"	1½	Water	149	6,108,000	125	Dry	
282	47	30	Compression	1	4	8	"	1½	"	145	4,397,000	1,346	Plastic	Good failure.
23		90	Tension	1	3		Medusa		Air dry	136	3,988,000	199	Dry	Failed in shoulder.
24		90	"	1	3		"		"	139	5,202,000	234	"	" " "
117	37	120	"	1	3		"		"	136	5,144,000	144	Very dry	
118	38	120	"	1	3		"		"	136	5,150,000	154	"	
235	53	95	"	1			"		Water	137	6,423,000	645	Plastic	Failed in head.
291	4	90	Compression	1			"		"	136	6,578,000	5,280	"	Sudden failure.
292	7	90	"	1			"		Air	129	3,940,000	4,580	"	" "

TABLE II.

SHOWING THE VALUES OF THE MODULUS OF ELASTICITY AND ULTIMATE STRENGTH OF VARIOUS MIXTURES OF CINDER-CONCRETE, AND THE EFFECT OF SETTING IN AIR AND IN WATER.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Parts of Sand.	Parts of Cinder.	Brand of Cement.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Ult. Comp. Str. in Lbs. per Sq. In. on Cubes.	Remarks.
43	65	7	Tension.	1	2	4	Atlas	Air	118	1,854,000	46		
44	66	7	"	1	2	4	"	"	114	1,892,000			Not broken.
46	68	7	"	1	2	4	"	Water	122	1,826,000			" "
49	1	7	Compression	1	2	4	"	"	120	514,000			" "
50	2	7	"	1	2	4	"	Air	116	876,000			" "
48	3	7	"	1	2	4	"	"	111	945,000			" "
141	66	30	Tension	1	2	4	"	"	113	2,800,000	133	993	
149	68	30	"	1	2	4	"	Water	121	2,909,000	77	1,415	Solid section. No flaw apparent at point of rupture.
152	1	30	Compression	1	2	4	"	"	119	1,358,000	993		
153	2	30	"	1	2	4	"	Air	112	1,626,000	1,049		
154	3	30	"	1	2	4	"	"	106	1,399,000	976		
159	69	30	Tension	1	2	5	"	"	109	2,853,000	86	1,039	
155	72	30	"	1	2	5	"	"	107	2,329,000	86	1,054	
167	73	30	"	1	2	5	"	"	102	1,820,000	78	688	
171	74	30	"	1	2	5	"	Water	126	1,900,000	76	1,166	
174	75	30	"	1	2	5	"	Air	112	1,900,000	129	1,005	
189	27	30	Compression	1	2	5	"	"	109	1,772,000	941		
190	28	30	"	1	2	5	"	Water	114	1,021,000	705		
132	51	60	Tension	1	2	5	"	Air dry	117	2,413,000	97	882	
138	9	60	Compression	1	2	5	"	"	114	1,055,000	573		
139	15	60	"	1	2	5	"	"	116	1,783,000	847		
140	16	60	"	1	2	5	"	"	119	1,152,000	670		
163	7	30	"	1	2	5	"	Water	114	1,168,000	682		
2		12	Tension	1	2	5	Medusa	Air dry	113	1,428,000	60		Mix very dry.

TABLE II.—Continued.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Composition. Parts of Sand.	Composition. Parts of Cinder.	Brand of Cement.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	Ult. Comp. Str. in Lbs. per Sq. In. on Cubes.	Remarks.
195	49	60	Tension	1	3	6	Atlas	Air dry	110	1,274,000	58	699	Mix very dry.
198	50	60	"	1	3	6	"	"	110	1,892,000	88	949	
203	47	60	"	1	3	6	"	"	107	2,215,000	62	677	Failed in head.
207	48	60	"	1	3	6	"	"	108	2,922,000	52		Failed in plane of micrometer screws.
216	10	60	Compression	1	3	6	"	"	107	917,000	734		
217	11	60	"	1	3	6	"	"	101	916,000	544		
186	79	30	Tension	1	3	6	"	Water	114	1,422,000	41	653	
192	30	30	Compression	1	3	6	"	Air		1,473,000	484		
193	31	30	"	1	3	6	"	"	107	1,447,000	511		
194	32	30	"	1	3	6	"	Water	118	751,000	500		
209	80	30	Tension	1	3½	7	"	Air	102	1,034,000	30	409	
212	81	30	"	1	3½	7	"	"	104	937,000	31	510	
218	33	30	Compression	1	3½	7	"	"	106	533,000	405		

TABLE III.

SHOWING TESTS IN TENSION ON CONCRETE MADE FROM LIMESTONE SCREENINGS.

No. of Test.	Marks.	Age in Days.	Kind of Test.	Composition. Parts of Cement.	Composition. Parts of Screenings.	Brand of Cement.	Treatment.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Ult. Str. in Lbs. per Sq. In.	REMARKS.
33	35	90	Tension	1	5	Medusa	Air dry	124	2,538,000	252	
34	36	90	"	1	5	"	"	119	1,051,000	140	Not explained.
289	33	135	"	1	5	"	"	121	2,224,000	238	
290	34	135	"	1	5	"	"	122	1,508,000	151	
293	62	97	"	1	5	Atlas	"	116	3,095,000	150	Made very dry.
294	17	97	Compression	1	5	"	"	118	1,714,000	1,238	" " "

TABLE IV.

SHOWING COMPRESSION TESTS ON CONCRETE MADE FROM LIMESTONE SCREENINGS. TESTS MADE ON WET AND DRY CONCRETE.

No. of Test.	Marks.	Height in Inches.	Section, Inches.	Area in Square Inches.	Ultimate Strength in Lbs.	Ult. Str. in Lbs. per Sq. In. Tested Dry.	Ult. Str. in Lbs. per Sq. In. Tested Wet.
298	33	3.5	3.2 x 2.94	9.41	13,240	1,407	
299	33	3.5	3.45 x 2.94	10.14	13,800		1,360
300	34	3.5	3.76 x 2.9	10.9	16,110	1,478	
301	34	3.5	3.24 x 2.9	9.39	10,500		1,118
302	35	3.5	3.32 x 2.95	9.79	14,640	1,495	
303	35	3.5	3.42 x 2.95	10.09	12,540		1,243
304	36	3.5	3.02 x 2.82	8.51	14,100	1,657	
305	36	3.5	3.32 x 2.82	9.36	10,050		1,075
306	62	3.5	3.1 x 3.02	9.36	9,100	972	
307	62	3.5	2.74 x 3.02	8.27	5,700		689

TABLE V.—SHOWING EFFECT ON TENSILE STRENGTH AND ELASTICITY OF WETTING ON CINDER CONCRETE.

No. of Test.	Marks.	Age in Days.	Composition. Parts of Cement.	Parts of Sand.	Parts of Cinder.	Brand of Cement.	Condition when Tested.	Weight in Lbs. per Cu. Ft.	Modulus of Elasticity.	Per Cent. of Absorption.	Ult. Str. in Lbs. per Sq. In.	REMARKS.
274	101	33	1	3	6	Atlas	Wet	110	920,000	7.59	51	Piece of coal in broken section.
275	102	33	1	3	6	"	Dry	111	1,856,000		93	Failed in plane of extensometer screws.
276	103	33	1	3	6	"	Wet	108	859,000	8.31	46	" " " "
277	104	33	1	3	6	"	Dry	110	2,571,000		95	Failed at shoulder.
278	105	32	1	3	6	"	"	112	3,093,000		65	Defective from adhering to mold.
279	106	32	1	3	6	"	Wet	110		8.06	22	Poor section.
280	107	32	1	3	6	"	Dry	110	1,953,000		102	Good specimen.
281	108	32	1	3	6	"	Wet	117	915,000	6.77	64	Very dense.

TABLE VI.—SHOWING EFFECT OF MOISTURE ON COMPRESSIVE STRENGTH OF CINDER-CONCRETE AND STRENGTH OF CONCRETE AFTER BEING DRIED.

No. of Test.	Marks.	Height of Specimen. Inches.	Section. Inches.	Area in Square Inches.	Ult. Str. in Lbs	Ult. Str. in Lbs. per Sq. In. when Tested Dry.	Ult. Str. in Lbs. per Sq. In. when Tested Wet.	Ult. Str. in Lbs. per Sq. In. after being Dried Out.
308	102	3.5	3.45 x 2.9	10.	9,000	900		
309	102	3.5	3.15 x 2.9	9.13	5,840		640	
310	*104	3.5	2.88 x 2.95	8.5	6,100	718		
311	104	3.5	2.9 x 2.95	8.55	6,500		760	
312	105	3.5	3.2 x 2.99	9.57	7,580	792		
313	105	3.5	2.6 x 2.99	7.77	4,950		637	
314	107	3.5	3.6 x 3	10.8	9,690	897		
315	107	3.5	2.97 x 3	8.91	6,110		686	
316	101	3.5	3.25 x 2.88	9.35	7,680		821	
317	101	3.5	3.8 x 2.88	10.94	11,090			1,014
318	103	3.5	3.92 x 2.91	11.41	9,380		822	
319	103	3.5	3.45 x 2.91	10.04	11,380			1,134
320	106	3.5	3.87 x 3.01	11.65	9,300		798	
321	106	3.5	4.08 x 3.01	12.28	10,790			879
322	108	3.5	3.67 x 2.96	10.86	7,730		712	
323	108	3.5	3.93 x 2.96	11.63	11,675			1,004

* Defective.

lower modulus of elasticity than the specimen protected from too rapid drying out for forty-eight hours. Stone concrete sets more rapidly in water than in air. Cinder concrete develops less strength when set in water than when set in air.

The tension specimens were made in cast iron moulds and had a sectional area of 10 square inches, being approximately $2\frac{7}{8}$ inches by $3\frac{1}{2}$ inches in cross-section, a length of reduced section of 14 inches, and an over-all length of 21 inches. Each specimen tested was measured for area of cross-section to the nearest hundredth of an inch.

The compression specimens were made in wooden molds with the same sectional area as the tension specimens and with a length of 11 inches, which is very nearly four times the least lateral dimension. The concrete was put into the molds in thin layers and each layer was well tamped to insure a uniform density.

Three brands of Portland cement were used in these tests,—viz, the Atlas, Lehigh and Medusa brands. The greater part of the test specimens were made with the Atlas brand of cement.

Unscreened Mississippi River sand, in the same condition in which it comes on the St. Louis market, was used for all tests.

The stone used was $1\frac{1}{2}$-inch and 2-inch limestone macadam, and this also was used for testing in the same condition in which it comes on the market. Voids in the 2-inch macadam measured by fine sand equal 43 per cent. Voids in $1\frac{1}{2}$-inch macadam measured by fine sand equal 46 per cent. Voids in sand used in measuring voids in macadam equal 34.3 per cent. Total voids to be filled in 2-inch macadam equal $57\frac{3}{4}$ per cent. Total voids to be filled in $1\frac{1}{2}$-inch macadam equal $61\frac{3}{4}$ per cent.

Cinders were used unscreened.

The stone and cinders were wet down in the pile to prevent their absorbing too much moisture from the mix. The sand and cement were thoroughly mixed dry and added to the stone or cinders in the mixing-pan.

All measurements were volumetric.

The cement was measured in such a way as would give very nearly, but not quite, the density of the original package and maintain a uniform density for all measurements.

The compression and tension tests were made on a Riehlé testing machine of 20,000 pounds capacity.

The deformations were measured by means of a dial extensometer having friction rollers. On this extensometer deformations of 0.0001 of an inch are read by means of a vernier needle. By using a good magnifying glass deformations of 0.00005 of an inch

were read very easily and quite accurately, as the platted curves prove. Elongations were measured in a gaged length of 10 inches. The gaged length in compression tests was 6 inches.

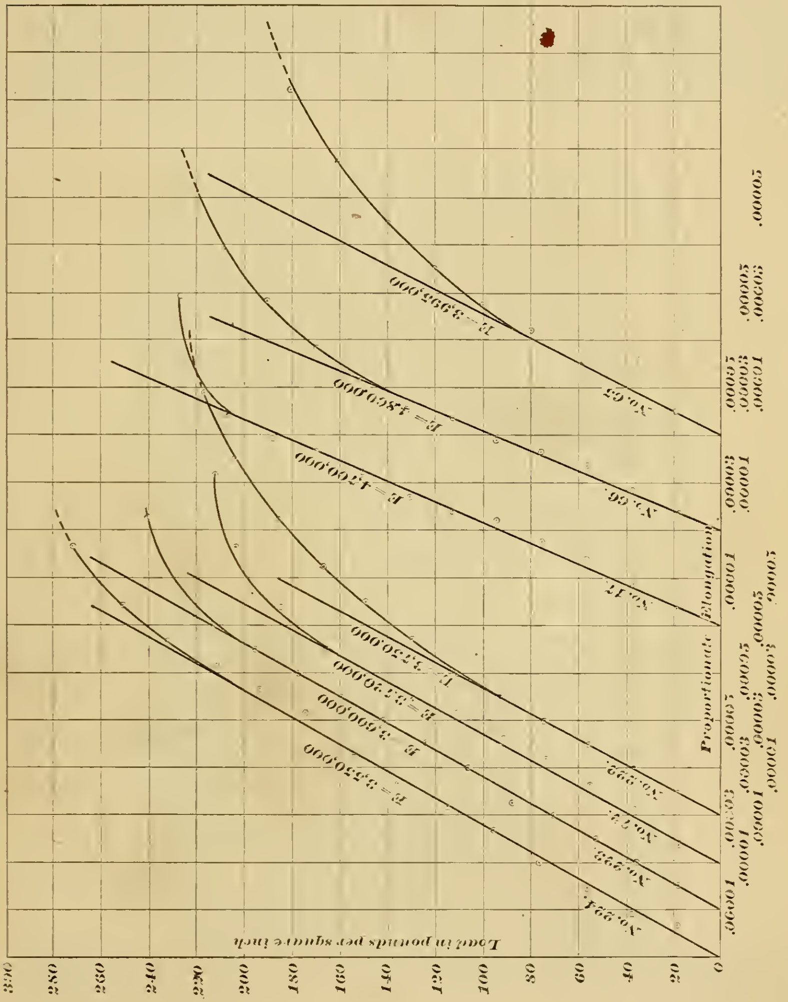

FIG. 1. SEVEN TENSION TESTS OF STONE CONCRETE.
Mix. 1 : 2 : 4. E = Modulus of Elasticity.

It has been found that repeated loading to the elastic limit, and even somewhat beyond it, does not materially affect the modulus of elasticity. After the concrete is thirty days old the rate of gain of the modulus of elasticity is very slow.

By so proportioning the component parts that the voids in each component part were filled with a small excess for safety by the component part of next smaller size, and by using no more

water in mixing than just enough to bring the mix to the proper consistency, the greatest strength and the highest values of the modulus of elasticity were obtained for the given class of materials.

The failure of specimens made to develop the maximum strength for the materials used was in planes in which all stones were broken across in the plane; this is true of both compression and tension tests. When the pieces of concrete are broken with

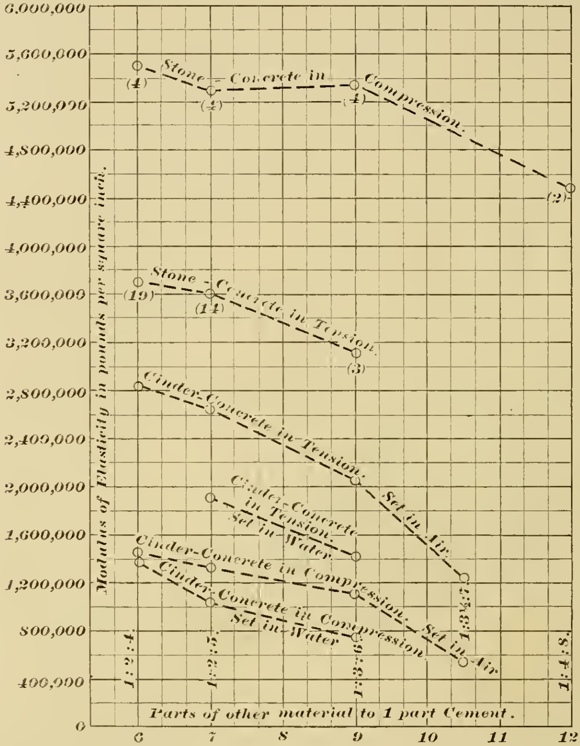

FIG. 2. MODULUS OF ELASTICITY FOR VARIOUS MIXTURES OF STONE AND CINDER CONCRETE IN TENSION AND COMPRESSION.

a hammer the planes of rupture go through stone and mortar alike, showing the mortar to be of equal strength with the limestone.

Numerous tests of different mixtures of cinder concrete have been made. Compression and tension test specimens were made from each mix to insure comparable results. At the time of testing each specimen was measured and weighed to determine the specific density, and in making comparisons between tension and compression tests only those tests having approximately the same density are taken into consideration.

Cinder Concrete, Wet and Dry. Table V shows the ratio of the ultimate tensile strength and modulus of elasticity between wet and dry cinder concrete of mixture with 1 cement, 3 sand, 6 cinders. The eight specimens were made in two mixes of four each; specimens marked 101, 102, 103 and 104 being of the same mix. All were set under damp cloths for forty-eight hours and then in dry air for a period of twenty-eight days, at the end of which

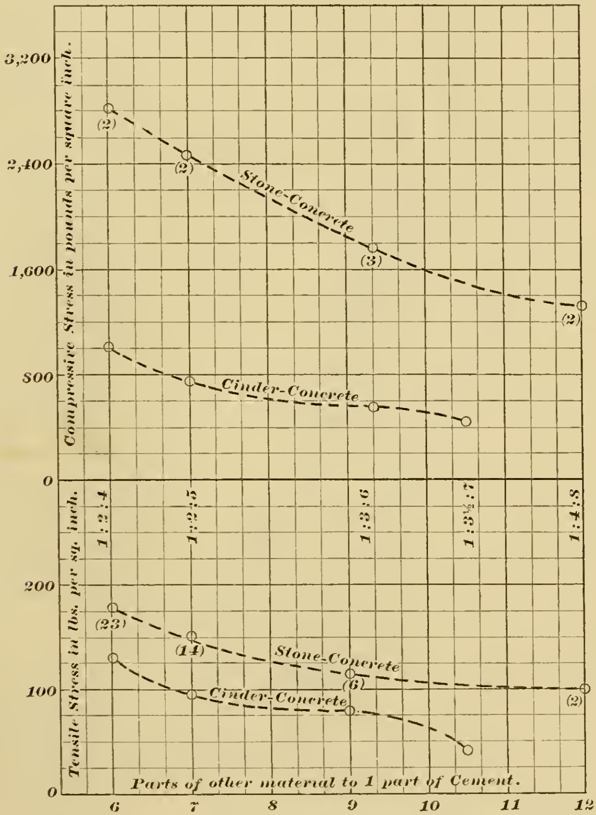

FIG. 3. STRENGTH OF STONE AND CINDER CONCRETE WHEN A MONTH OLD.

time two of each batch of four were put in water for a further period of three days, at the end of which time all were tested to rupture. The average tensile strength of the four tested dry was 89 pounds per square inch, while the average tensile strength of the four tested wet was 46 pounds per square inch. The average tensile modulus of elasticity of those tested dry was 2½ times the average modulus of elasticity of those tested wet.

Table VI shows the ratio between the ultimate compressive strength of wet and dry cinder concrete. From each of the tension specimens, the results of tension tests of which are given in

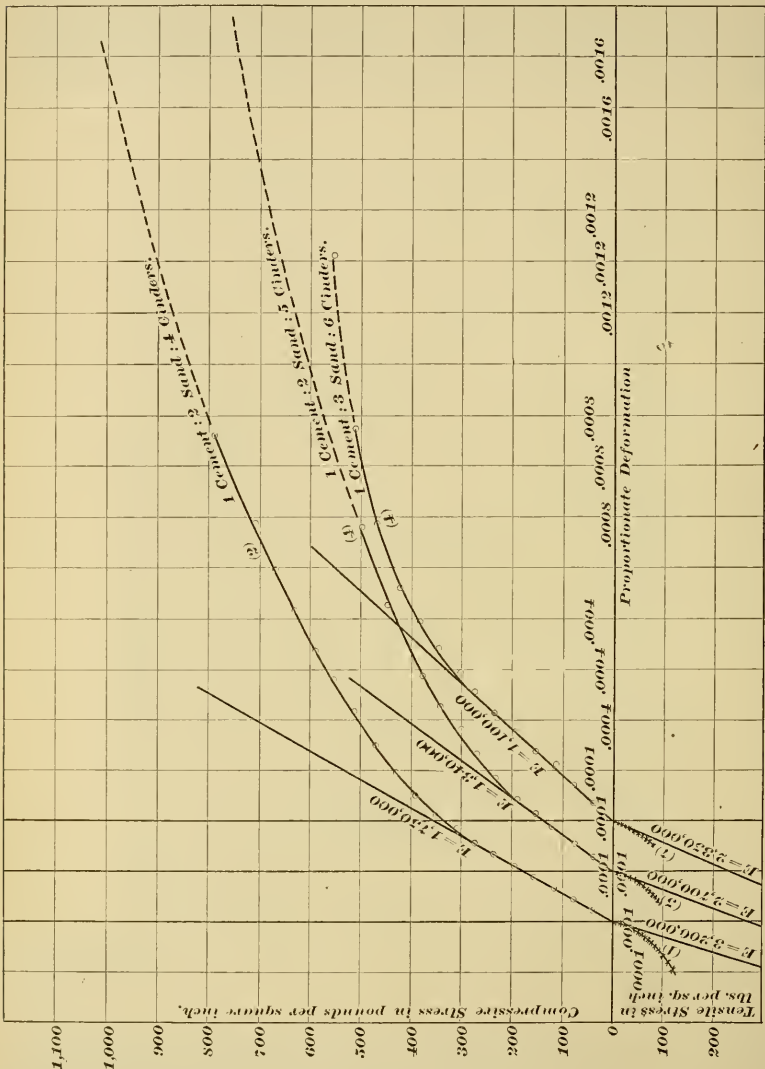

FIG. 4. AVERAGE CURVES OF COMPRESSION AND TENSION TESTS OF CINDER CONCRETE WHICH ARE COMPARABLE WITH CINDER CONCRETE BEAMS TESTED.

E = Modulus of Elasticity.

Table V, two compression specimens, approximating cubes, were taken. One of each of these two compression specimens was immediately tested for ultimate compressive strength. Of the other eight specimens, the four which were dry were put into the water bath for forty-eight hours and then tested wet, while the four wet

cubes were dried in a temperature of 125° F. for forty-eight hours and then tested dry. In all these tests the load was applied slowly. This table shows this concrete to have been one-third stronger, under compressive stress, when dry than when wet.

A series of tests on concrete of 1 cement, 5 limestone screenings showed the concrete to be 28 per cent. stronger when dry than when wet.

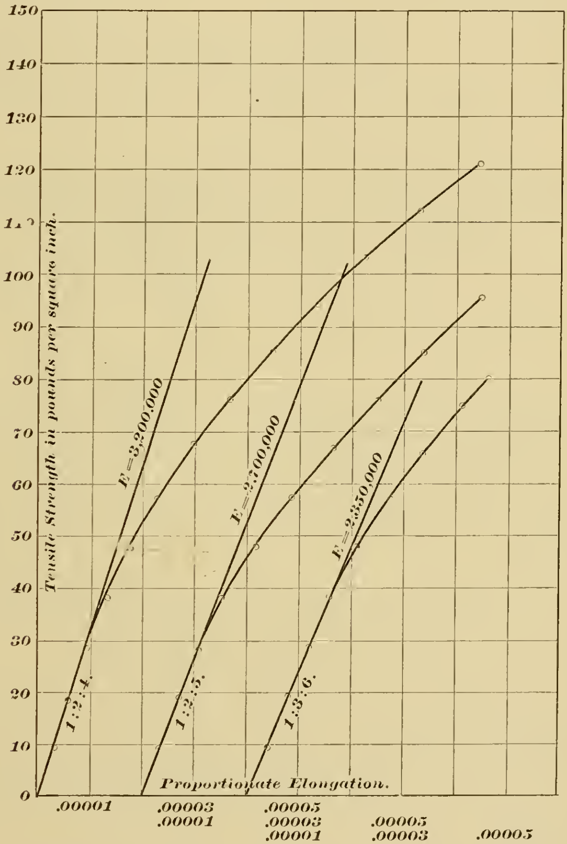

Fig. 5. Average Tension Curves of Cinder Concrete Shown to a Smaller Scale in Fig. 4.

E = Modulus of Elasticity.

Fig. 1 presents graphically the tests of seven stone concrete specimens in tension. The composition of each of these test specimens was 1 cement, 2 sand, 4 broken stone ($1\frac{1}{2}$-inch limestone macadam). Nos. 72, 222, 223 and 224 were made from the same mix. No. 72 was tested to rupture at seven days old. Nos. 222, 223 and 224 were loaded to 120 pounds per square inch at

seven days old, and tested to rupture at thirty days old with loadings and deflections as shown in the figure. The four were set under damp cloths for forty-eight hours, and then in dry air until tested, with the exception of No. 224, which was set in water. The tests shown in the figure are representative tests of stone concrete in tension.

Fig. 2 presents, graphically, the average values of the modulus of elasticity given in Tables I and II. In attaining these averages the values obtained from the tests of specimens whose broken sections showed the specimen to be defective were not included, so that these values may be taken to be fairly accurate for well-mixed and well-tamped "dry" concrete.

The numbers in parenthesis at each point on the curves indicate the number of tests averaged to obtain that point.

The average density of the stone concrete compression specimens was found to be greater than the average density of the tension specimens. This may account to a great extent for the much higher values of the compression modulus of elasticity of stone concrete.

The cinder concrete compression and tension specimens were of approximately the same density and were in all respects comparable. The higher values of the tension modulus of elasticity are characteristic, with hardly an exception, in a long series of experiments. This figure also shows the effect of setting cinder concrete in water.

In Fig. 3 is shown the strength of various mixtures of concrete. The compression tests were made on specimens whose height was four times the least lateral dimension.

In Fig. 4 average compression and tension curves of these mixtures of cinder concrete are shown in full. Only such tests as were comparable were used in making these average curves. This figure shows the ratio between the compression and tension moduli of elasticity, and the ratio between the ultimate compressive and tensile stresses.

In Fig. 5 the tension curves, shown to a small scale in Fig. 4, are shown to a much larger scale.

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WATER MEASUREMENTS IN CONNECTION WITH A TEST OF A CENTRIFUGAL PUMP AT JOURDAN AVENUE DRAINAGE STATION, NEW ORLEANS, LA.

BY W. M. WHITE, B.E., MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, October 8, 1900.*]

THE Jourdan avenue drainage station is situated at the intersection of the Jourdan avenue and Florida Walk canals. It drains the lower section of the city and discharges its water into an outfall canal, which empties into Bayou Bienvenue and thence into Lake Borgne. The station is equipped with two centrifugal pumps of the Guynne type, designed by the eminent hydraulician John Richards, of San Francisco, each being direct-connected to a 400 horse power triple-expansion condensing engine. Each pump has a capacity of 150 cubic feet per second when discharging against a head of 12 feet. The pumps are placed above the level of the discharge basin, the center line of the pumps being about 8 feet above the surface of the discharge canal; but the discharge pipes are submerged, so that the pumps get the benefit of the siphonic action of the water in flowing from the higher level of the pumps to the lower level of the discharge basin. Most of the pumping is done from a 2-foot to an 8-foot lift. The pumps are designed to run at 125 revolutions per minute at the 12-foot head.

OBJECT OF THE TEST.

This test was made to determine at what number of revolutions to run the pump for the different heads pumped against, in order to obtain the highest efficiency of the engine and pump com-

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bination. A comparison of the engine and pump horse power was made for different revolutions, while the head pumped against remained constant. That number of revolutions which gave the highest efficiency for the head was selected, and the pump is to be run at that number of revolutions when pumping against the corresponding head.

In making the test the suction basin was allowed to fill, in order to get a reading for the lowest head pumped against. The pump was then run at the highest possible number of revolutions, and readings of the engine and pump horse power were taken simultaneously. The pump was slowed down by equal decrements of ten revolutions until the lowest practical number of revolutions had been reached, taking the same readings of engine and pump

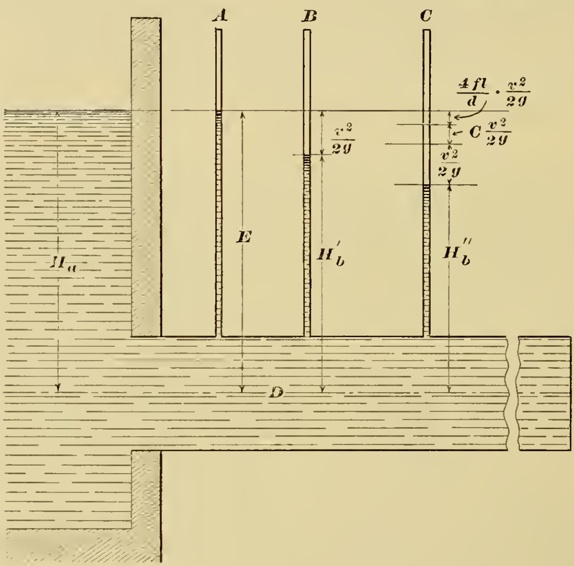

FIG. 1.

horse power at each decrement of revolutions. The reason for beginning at the highest number of revolutions was that the head pumped against might be kept constant. At the highest number of revolutions the velocity of water in the canals was greatest, consequently the velocity drop in the canals was greater than at the lower number of revolutions. During a reading the canals were lowered slightly, but when the pump was slowed down the water in the suction basin rose just enough to keep the head pumped against constant. After these readings were made the canals were

pumped down one foot and similar readings were taken, thus determining the number of revolutions giving the highest efficiency for each head.

THE ENGINE HORSE POWER.

The engine horse power was determined in the ordinary way, by using indicators and counting the number of revolutions. The indicators used were all Crosby instruments, and in good condition. They were not calibrated, as it was thought the percentage of error in them would be slight in comparison to the errors in some of the other observations.

THE PUMP HORSE POWER.

In determining the pump horse power the question of the velocity of the water through the pipes was a serious problem. In finding the velocity three methods were used, which were more or

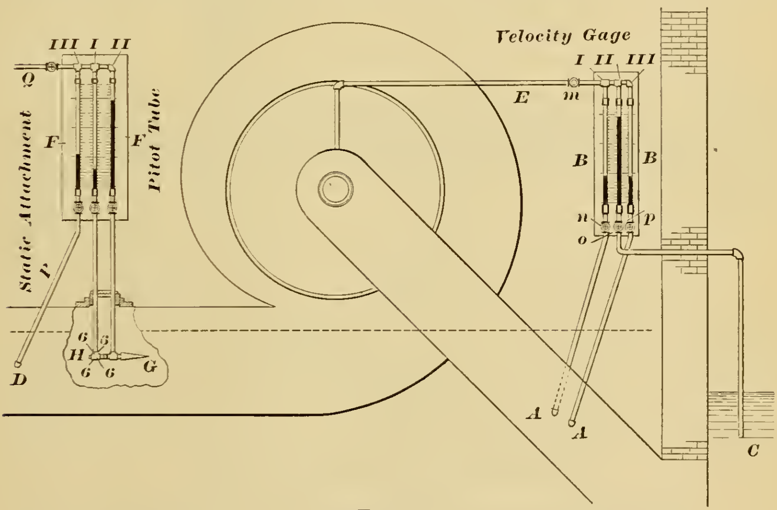

Fig. 2.

less dependent upon each other. On the first day's test a velocity gage, designed by the writer, was used on the suction side of the pump and a Pitot tube on the discharge side (see Fig. 2). The Pitot tube was found to give a higher velocity than existed, and on the second day of the test a static attachment was used in connection with it. By means of these methods, using them as checks against each other, the velocity in the pipes was determined within a small percentage of the true velocity. Knowing the velocity in feet per second, and the area in square feet of the cross-section of the discharge pipe, the number of cubic feet discharged per second was determined. Then the number of cubic feet discharged per

second, multiplied by the head discharged against (or the difference between the water levels of the suction and discharge basins) and by 62.3, gave the number of foot-pounds of water delivered per second, and this, divided by 550, gave the pump horse power.

THE VELOCITY GAGE.

The velocity gage is a device that suggested itself to the writer for determining the velocity of water in a pipe that takes its water from a basin. It embraces no new principles, but is an application of known hydraulic laws to local conditions. It depends for its action upon Bernouilli's thoerem, which says that "in steady flow without friction the sum of the velocity head, pressure head and potential head at any section of the pipe is a constant quantity, being equal to the sum of the corresponding heads at any other

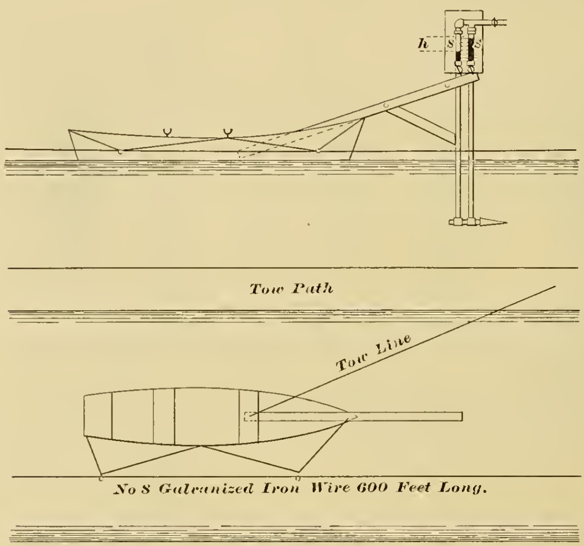

Fig. 3.

section." According to this law, the hydraulic pressure of flowing water against the interior of the pipe containing it is equal to the hydrostatic head (or the pressure which would exist if the water were at rest), less the head causing the velocity. If a vertical pipe A is connected with the pipe D, Fig. 1, leading from the basin, water will rise in the pipe A to a height E, which measures the pressure of the water against the interior of the pipe D at the foot of pipe A. If the pipe D is closed beyond A, the hydraulic pressure E will be equal to the hydrostatic pressure H in the basin; but if water flows through the pipe D the pressure at A must be less than

H_a, otherwise there would be no tendency for the water to move. Suppose that the hydraulic pressure in the pipe D was J, measured in feet of water, then K (= H — J) is the difference of pressure between the basin and the pipe D, expressed in feet of water, and is the pressure tending to set the water in motion from the basin to pipe B, or is the velocity head or the pressure which gives it the velocity of flow.

From Bernouilli's theorem we have, neglecting friction:

$$H_a + H_b + \frac{v^2}{2g} = H_a^1 + H_b^1 + \frac{v^{12}}{2g}$$

Where H_a, H_a^1 = hydrostatic head at two points respectively.

H_b, H_b^1 = hydraulic head at two points respectively.

$\frac{v^2}{2g}$ $\frac{v^{12}}{2g}$ = velocity head at two points respectively.

Substituting the values in Fig. 1, we have:

$$H_a + o + o = o + H_b + \frac{v^{12}}{2g}$$

$$H_a = H_b^1 + \frac{v^{12}}{2g}$$

To make the foregoing equation complete it is necessary to take into consideration the loss of head due to the abrupt opening from the basin into the pipe, and that due to the friction in the pipe. Both of these quantities are functions of the velocity, and are determined by constants multiplied into the velocity head. The loss of head due to friction in the pipe is given by

$$\frac{4\,f\,l}{d}\,\frac{v^{12}}{2g}$$

Where f is the coefficient of friction, l is the distance from the opening of the pipe to the point where the hydraulic pressure is measured, and d is the diameter of the pipe. The loss of head due to the abrupt entrance is $c\,\frac{v^2}{2g}$, and the completed equation becomes:

$$H_a = H_b'' + \frac{v^2}{2g} + c\,\frac{v^2}{2g} + \frac{4\,f\,l}{d}\,\frac{v^2}{2g}$$

Solving for V,

$$V^2 = \frac{1}{1 + c + \frac{4\,f\,l}{d}}\,2g\left(H_a - H_b''\right)$$

and representing $H_a - H_b''$ by h

$$\text{and } \frac{1}{1 + c + \frac{4\,f\,l}{d}} \text{ by } \Phi^2$$

the equation can be written:

$$V^2 = \Phi^2\,2gh$$

$$V = \Phi\,\sqrt{2gh}.$$

In calculating the value of Φ, the term representing the loss of head due to friction may be neglected, since the hydraulic head is measured close to the mouth of the pipe. (See Fig. 1.)

The value of c is usually given as 0.5. Substituting these values:

$$\Phi^2 = \frac{1}{1 + 0\ 5 + 0} = \frac{2}{3}$$

$$\Phi = \sqrt{\tfrac{2}{3}} = 0.\ 815$$

In using the velocity gage, the value of Φ would have to be determined by calibration, as the value of c depends upon the opening into the suction basin.

Supposing a velocity of 5 feet per second in the pipe, we have:

$$V = 0.\ 815 \sqrt{2gh}.$$

$$5 = 0.\ 815 \sqrt{2gh}.$$

$$h = 0.59 \text{ foot}.$$

This gives a difference ($H_a - H_b''$) of 0.59 of one foot, which can be read without difficulty.

Suppose V = 6 feet per second, then $6 = 0.815 \sqrt{2gh}$. $h = 0.843$. This gives a difference of reading $H_a - H_b''$ of 0.02 of a foot for each increment or decrement of one inch velocity per second between 5 feet and 6 feet flow per second. The greater the velocity the more accurate the reading, the accuracy of the reading increasing as the square of the velocity.

PLACING THE VELOCITY GAGE.

At the Jourdan avenue pump two velocity gages had to be used, as there are two suction pipes.

In the suction pipes of the pump at A, A, Fig. 2, holes were drilled and tapped for ¼-inch gas pipes, and the ends of these pipes were not allowed to protrude into the interior of the suction pipes, and care was taken to remove all burrs from the inside of the pipe. Quarter-inch gas pipes were led from these holes to the scale BB, which was placed on the station wall. From experiments that have been made by Clemens Herschel, the tapping of the pipe in one place seems to be as good an arrangement as a piezometer for giving the hydraulic pressure. A third ¼-inch gas pipe was led from a still part of the suction basin C. The three pipes terminated in three ¼-inch glass tubes, I, II and III, which were fastened vertically on the scale BB. The tops of the tubes were joined to the same exhaust pipe E. The scale, BB, is 6 feet long, and graduated to 0.02 of a foot. It is placed behind the glass tubes, so that the three water levels are read on the same scale.

The exhaust pipe E, from the top of the tubes, was led back to the highest point of the suction pipe, and the scale BB was placed at such level as would bring the water levels on the scale; m, n, o and p are ¼-inch valves used to control the fluctuations in the water

columns, so that accurate readings could be made on the scale. Tubes I and III lead from the suction pipes, while tube II leads from the suction basin. The reading II — I gives h in calculating the velocity in pipe No. 1, while the reading II — III gives the same value for pipe No. 2.

PITOT TUBE.

The Pitot tube is an instrument for converging velocity head into hydrostatic head and measuring the hydraulic head, the difference between the hydrostatic and hydraulic heads being the velocity head, or h in the formula $V = \sqrt{2gh}$. For convenience in reading these water levels a scheme somewhat similar to that of the velocity gage was used (see FF, Fig. 2). Here tube II is connected with the point G, and gives the hydrostatic head, while tube I is connected to the hydraulic or rear part of the tube. This part should have been designed so that the water in rushing past the holes 6, 6, 6 did not have any impelling or suction action, giving only the hydraulic head.

The Pitot tube used in the test is one belonging to Tulane University. The constant of the instrument was supposed to be unity. The Pitot tube was placed in the discharge pipe of the pump, and was so arranged that it could be raised or lowered in the pipe and the velocity of the different strata of the water determined. The pipe was kept sealed at all times, and a vacuum of about 2 inches of mercury was maintained at the top of the discharge pipe within the pumping station. During an observation at first five, and later nine, readings were taken in quick succession, the positions of the point ranging from 2 inches below the top of the pipe to 5 inches above the bottom. When nine readings were taken, five were observed while lowering the tube and four while bringing it up. An average of these readings was taken as the average velocity of an observation. Another method of getting the average velocity of flow was by imagining concentric rings in the discharge pipe, calculating the cubic feet discharged for each ring and working back to an average velocity. This result was found to agree, within 0.5 per cent., with the first method, and it was discarded in favor of the first method.

STATIC ATTACHMENT.

After the first day's test it was found that the readings of the Pitot tube were too high, as compared with those of the velocity gage. For instance, notice observation No. 1, Table No. I. The Pitot tube gives the average velocity 17.91 feet per second. The velocity gage gives the average velocity as 16.92 feet per second

TABLE I.

Number of Observation.	Number of Reading.	Pitot Tube Reading. Scale Reading. I.	Pitot Tube Reading. Scale Reading. II.	Difference II − I = h in $V = \sqrt{2gh}$.	Velocity $V = \sqrt{2gh}$.	Average Velocity.	Velocity Gage Reading (Simultaneous). Scale Reading. I.	Scale Reading. II.	Scale Reading. III.	Difference. h. II—I.	Difference. h^1. III—II.	Velocity in Pipe No. 1.	Velocity in Pipe No. 2.	Average Velocity.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	0.9	5.8	4.9	17.69		0.58	5.14	0.72	4.56	4.42	17.05	16.75	
	2	0.9	5.8	4.9	17.69		0.55	5.1	0.72	4.55	4.38	17.03	16.72	
	3	1.1	6	4.9	17.69		0.5	5.08	0.68	4.58	4.4	17.1	16.73	
	4	1.1	6.15	5.05	17.98		0.57	5.16	0.72	4.59	4.44	17.11	16.81	
	5	1.2	6.3	5.1	18.5		0.57	5.12	0.72	4.55	4.4	17.03	16.73	
						17.91					Average	17.06	16.79	16.92

TABLE II.

Number of Observation.	Number of Reading.	Pitot Tube and Static Attachment Reading. Scale Reading. Rear I.	Scale Reading. Point II.	Scale Reading. St. At. III.	h. P. T. II − I.	h^1. St. At. II − III.	Velocity by Pitot Tube. $V = \sqrt{2gh}$.	Velocity by Static Att. $V = \sqrt{2gh}$.	Velocity Gage Reading (Taken Simultaneously). Scale Reading. I.	Scale Reading. II.	Scale Reading. III.	Difference. h. II − I.	Difference. h^1. II − III.	Velocity in Pipe No. 1.	Velocity in Pipe No. 2.	Average Velocity.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
18	1	0.5	4.04	1.32	3.54	2.72	15.04	13.14	0.42	4.7	2.3	4.28	2.4	16.54	12.38	
	2	0.52	4.06	1.52	3.54	2.54	15.04	12.7	0.43	4.64	2.3	4.21	2.44	16.4	12.48	
	3	0.7	4.34	1.68	3.64	2.66	15.25	13	0.43	4.7	2.31	4.27	2.39	16.53	12.36	
	4	0.8	4.52	1.82	3.72	2.7	15.42	13.1	0.43	4.76	2.3	4.33	2.46	16.6	12.51	
	5	0.74	4.6	1.88	3.86	2.72	15.7	13.14	0.44	4.78	2.30	4.34	2.48	16.64	12.58	
	6	0.6	4.56	1.6	3.96	2.96	15.9	13.7	0.42	4.64	2.28	4.22	2.36	16.42	12.28	
	7	0.33	4.26	1.38	3.93	2.88	15.84	13.55	0.42	4.62	2.26	4.2	2.36	16.38	12.28	
	8	0.1	3.9	1.2	3.8	2.7	15.58	13.1	0.42	4.64	2.24	4.22	2.4	16.42	12.38	
	9	0.2	3.6	0.82	3.4	2.78	14.7	13.3	0.42	4.64	2.26	4.22	2.38	16.42	12.32	
						Average	15.38	13.2					Average	16.48	12.40	14.44

without the introduction of the constant ϕ, which would never be as great as unity, so that the true velocity must be less than 16.92 feet per second.

The point of the Pitot tube, G, Fig. 2, is made according to the Darcy principle, and is correctly designed to give the hydrostatic head. The hydraulic, or rear part H, of the tube, Fig. 2, is not made according to the Darcy principle, and the conclusion was reached that this part of the tube was responsible for the error in the reading. As this part of the tube is intended to give the hydraulic head of the pipe, it occurred to the writer to tap the pipe at D, and obtain the hydraulic head in this way. Accordingly, a hole was drilled at D and tapped for a $\frac{1}{4}$-inch gas pipe, care being taken, as before, not to have any burrs and not to allow the pipe to protrude into the discharge pipe. This pipe, P, terminated in a glass tube, III, on the Pitot tube scale, the top of the tube being connected with the common exhaust pipe Q. This gave three water levels on the scale. The tube III gives the hydraulic head by the static attachment, II the hydrostatic head and I the hydraulic head, as given by the Pitot tube. Column eight, observation No. 18, Table No. II, gives the velocity determined by the Pitot tube; column nine that determined by the static attachment, and column seventeen that determined by the velocity gage. By a comparison of the velocities it is seen that the Pitot tube reading is 15 per cent. higher, and the velocity gage 10 per cent. higher, than that of the static attachment. Taking the latter as correct, and from it calibrating the Pitot tube by dividing the reading of column nine by the reading of column eight, the constant K was found to be 0.856, and calibrating the velocity gage in the same way gave the constant $\phi = 0.88$. This agreed so closely with the theoretical value of the constant that the reading of the static attachment was taken as correct. As a further check, the Pitot tube was calibrated by hauling it in front of a rowboat.

CALIBRATION OF PITOT TUBE.

The Pitot tube was calibrated in the Jourdan avenue canal (see Fig. 3). The canal is blanked off at one end. It consequently has very little current, and offers exceptional advantages for a calibration of this kind. For a course a No. 8 galvanized iron wire was stretched 600 feet just above the surface of the water. A point was marked off on the wire 50 feet from each end. These were used as starting and stopping points, and left between them a clear measured course of 500 feet. The 50 feet on each end was used to get a start before crossing the line, and to check the head-

way after crossing the line. By means of cords attached at bow, amidships and at stern, a rowboat was fastened to awning pulleys running on the wire. The boat was hauled with a tow line by men running on the bank. The awning pulleys and wire held the boat in a straight course. The greatest tendency of the wire to pull to one side was at the center, but in no case did the boat swerve more than 24 inches. The Pitot tube was fastened by means of an outrigger 3 feet in front of the boat, and the point of the tube was submerged 2 feet below the surface of the water. Glass tubes,

TABLE III.

Calibration of Pitot Tube.

Number of Observation.	Direction. D = Down.	Distance in Feet.	Time in Seconds.	Velocity in Feet per Second.	Average Scale Reading in Feet. I	Average Scale Reading in Feet. II	Difference II − I = h.	Velocity from $V = \sqrt{2gh}$.	$K = \frac{\text{True Vel.}}{\sqrt{2gh}}$.
1	Up	500	102.5	4.87	Experimental Reading.				
2	D	500	101.5	4.925	0.28	0.799	0.519	5.776	0.854
3	Up	500	102.8	4.876	0.1804	0.674	0.486	5.64	0.863
4	D	500	95.3	5.249	0.115	0.72	0.605	6.24	0.842
5	Up	500	81	6.175	0.545	1.304	0.759	6.985	0.884
6	D	500	145	3.45	0.735	1.008	0.273	4.195	0.823
7	Up	500	98.7	5.07	0.613	1.174	0.561	6.015	0.843
8	D	500	75.3	6.64	0.92	1.885	0.965	7.875	0.843
9	Up	500	Failed to Catch the Time						
10	D	500	73.4	6.815	0.874	1.923	1.049	8.23	0.83
11	Up	500	120	Tube Stopped Up.					
12	D	500	76.4	6.548	0.787	1.779	0.992	7.99	0.82
13	Up	500	77.3	6.465	0.813	1.703	0.89	7.57	0.855
14	D	500	The Boat-Hauler Fell.						
15	Up	500	76	6.58	0.78	1.708	0.928	7.725	0.852
16	D	500	74.5	6.715	0.684	1.656	0.972	7.91	0.85
17	Up	500	102.2	4.89	0.853	1.343	0.49	5.62	0.869
18	D	500	91.9	5.44	0.784	1.406	0.622	6.325	0.86
								Average K =	0.849

$V = K\sqrt{2gh} = 0.849\sqrt{2gh}$. For Pitot Tube.

S, S, with a graduated scale behind them, faced the boat. These tubes were terminations of the point and rear pipes of the Pitot tube. They were joined together at the top, and the air was exhausted until water rose in them and its level could be read on the scale. Two men were seated in the boat. One was timekeeper, and with a stop watch noted the time occupied in traversing the 500 feet course. The other read as rapidly as possible the water levels on the scale. An average of these readings was taken, the difference of the averages giving h in the equation $V = \sqrt{2gh}$.

In going over the course the boat was hauled with as uniform speed as possible. The velocity in feet per second ranged from 3.45 to 6.8. In order to eliminate errors due to any current in the canal, the boat was reversed after each observation, and a reading was taken in going back over the course. The readings 1, 3, 5, etc., Table III, were taken in traveling up the canal toward the river, while readings 2, 4, 6, etc., were taken in traveling down the canal toward the pumping station. The up readings gave a little higher value of K than the down readings, showing a slight current in the canal; but this error was eliminated when the two were averaged.

The distance in feet divided by the time in seconds gave the true velocity in feet per second. The reading of the tube II minus the reading of the tube I gave h in the formula $V = \sqrt{2gh}$. This gave the Pitot tube velocity. Dividing the true velocity by the calculated velocity ($V = \sqrt{2gh}$), the quotient gave the value of the constant K. The true velocity is $K\sqrt{2gh}$ for the Pitot tube readings.

An average of fourteen observations, Table III, gave the value of $K = 0.849$, a difference of 0.7 per cent. as compared with the calibration by the static attachment.

DISCUSSION OF RESULTS.

Table No. IV gives the results of the three measurements in tabulated form. Each observation from 1 to 13 is a mean of five, and each from 13 to 29 is the mean of nine readings. Columns one, two and three give the readings of the Pitot tube, static attachment and velocity gage respectively, as calculated from the formula $V = \sqrt{2gh}$, without the introduction of any constant. Column four is a calibration of the Pitot tube from the static attachment by dividing the readings in column two by the readings in column one. Certain readings were rejected because the discharge pipe was not full of water, and because air then gathered in the pipe leading to the scale, rendering the readings unreliable. Column five is the Pitot tube reading multiplied by 0.849. This would be the true velocity, and would give the cubic feet discharged if the discharge pipe were full at all times. At a slow velocity of revolutions air would gather in the discharge pipe, and it would be running only half full of water.

Column six is the calibration of the velocity gage by dividing the observations of column three by the corresponding observations of column five. Only those observations that were taken when the discharge pipe was running full are used in determining the value for the velocity gage readings. The average of fourteen observations gives the value of $\phi = 0.881$. Multiplying the readings of column three by 0.881, the true velocity is obtained, as shown in column seven, and these were the velocities used in finding the pump

horse power. The Pitot tube readings cannot be used in determining the true velocity, because if the pipe is not full the cross-section of the discharged water is a variable quantity and difficult to determine. The suction pipe is full at all times, so that the velocity gage readings are the only ones that can be used.

TABLE IV.

Number of Observation.	Velocity by Pitot Tube where $V = \sqrt{2gh}$.	Velocity by Static Attachment where $V = \sqrt{2gh}$.	Velocity by Velocity Gage where $V = \sqrt{2gh}$.	Calibration of Pitot Tube from Static Attach. $= \frac{\text{Column 2}}{\text{Column 1}}$	Column 1 x 0.819 for P. T. Corrected $V = K\sqrt{2gh}$ $= 0.819\sqrt{2gh}$.	Calibration of Velocity Gage $= \frac{\text{Column 5}}{\text{Column 3}}$	True Velocity = Column 3 x 0.881 $V = \phi\sqrt{2gh} =$ $0.881\sqrt{2gh}$.	Remarks.
	1	2	3	4	5	6	7	
1	17.91		16.92		15.20	0.898	14.9	
2	15.56		15.23		13.20	0.867	13.41	
3	13.15		12.92		11.17	0.863	11.38	
4	12.47		11.95		10.57	0.885	10.53	
5	11.52		8.54		9.77	A	7.52	
6	12.67		10.23		10.77	A	9.01	
7	13.47		12.68		11.42	A	11.15	
8	13.27		12.83		11.25	0.877	11.3	
9	12.14		11.54		10.3	0.892	10.18	
10	12.32		9.25		10.46	A	8.15	
11	11.55		8.25		9.8	A	7.26	
12	9.94		6.61		8.43	A	5.825	
13	15.63		15.27		13.28	0.87	13.44	
14	13.88		13.75		11.78	0.857	12.11	
15	12.03		11.71		10.2	0.871	10.31	
16	13.09		10.12		11.1	A	8.92	
17	11.85		8.41		10.07	A	7.405	
18	15.38	13.2	14.44	0.859	13.06	0.904	12.72	
19	13.2	12.06	13.49	B	11.2	A	11.88	
20	12.27	10.4	11.4	0.853	10.41	0.913	10.03	
21	11.87	10.41	8.81	B	10.08	A	7.76	
22			6.53			A	5.75	
23	15.19	13.36	14.91	0.88	12.89	0.863	13.13	
24	13.52	11.56	12.85	0.855	11.48	0.893	11.32	
25	11.31	9.74	10.85	B	9.6	A	9.56	
26			8.23			A	7.25	
27	12.77	12.01	12.43	B	10.82	A	10.95	
28	10.54	8.79	10.12	0.834	8.95	0.885	8.92	
29			8.36			A	7.36	
		Average K =		0.856	Av. ϕ =	0.881		

NOTE A—Discharge pipe not running full.
NOTE B—Air bubbles caught in Static Attachment tube and the reading is not reliable.

I am indebted to Professor W. B. Gregory, of Tulane University, for the loan of the Pitot tube used in the test, for many valuable suggestions and for his assistance in working up the results. I am also deeply indebted to Mr. Alfred Raymond, general manager of the Drainage Commission, for his assistance, interest and encouragement in the work.

PUMPING BY COMPRESSED AIR.

By Edward A. Rix, M.E.

[Read before the Technical Society of the Pacific Coast, August 3, 1900.*]

My object in reading this paper is not to enter into an elaborate description of the various methods of compressed air pumping, but rather to touch on points which seem to have been heretofore neglected by those who have written on the subject, to suggest some new methods, and, if possible, to encourage the builders of pumping machinery to design pumps specially adapted to the use of compressed air.

From the very beginning compressed air has been handicapped, in the matter of pumping, because it has been used with stock pumps designed in general for boiler feeding and tank purposes, and no particular regard has been paid to matters of cylinder proportions and to appropriate pressures. Compressed air users, in the same manner, have been obliged to utilize old steam motors of all kinds, the general supposition being that steam motors are equally adapted for the use of compressed air. I will plead guilty to having committed this error on many occasions, and the remarkably poor efficiencies which I have obtained have led me to investigate the matter and to become a firm advocate of the designing of special motors for compressed air machinery. Great attention is paid to designing motors for the use of steam, even to the very smallest detail, and yet compressed air, which is almost doubly as expensive as steam to produce, has been compelled to take any misfit for its use. It has been condemned right and left for lack of economy, and has had a difficult time to maintain its proper existence in the face of the results it has produced in many cases with motors which were designed for something entirely different.

Those who are informed on the subject are perfectly well aware that while steam and compressed air follow in general the laws of perfect gases, their phenomena are sufficiently dissimilar to forbid their use in the same motor, the general difference being that for similar terminal pressures the points of cut-off are different. Air does not condense and it is therefore capable of indefinite multiple reheating.

There has been sufficient development made in the line of air compressors, and the attention of manufacturers should turn to the constructing of economical air motors. Among the first to inaugurate this reform should be the pump builders; for pumps, as

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ordinarily furnished for compressed air use, have the lowest economy of any compressed air machinery, not even excepting a rock drill.

It is not necessary to revolutionize shop methods nor to carry an expensive stock of specially designed pumps in order to accomplish the results desired. Merely pointing out to an intelligent customer the fact that his pocket will be vastly benefited by having a pump specially constructed for his work should be a great help at the moment, and as soon as it becomes generally known that great advantages are to be gained thereby many will abandon the old methods and the reform will be inaugurated.

In this paper I shall endeavor to point out some economical methods of pumping water by compressed air, and to suggest how others might be accomplished.

Let us consider generally the various methods used to lift water by compressed air, and to compare them in such a manner that those interested may better understand the subject, thus enabling them to improve upon these methods when occasion offers. To those who believe that compressed air occupies an economical as well as a useful field it is discouraging to see the various tables, rules and computations offered to the public for calculating the amount of air required to lift water, without a word of explanation that might temper the almost general conclusion that compressed air is a very expensive luxury. It would require a stout heart and a long purse to put in a compressed air pumping plant if the verdict of the various quantity tables were final. One consulting these authorities would inevitably conclude that the efficiencies were so low that only pressing utility would decide in favor of compressed air.

The percentage of efficiency credited to compressed air, in these tables, ranges from 15 per cent. to 30 per cent. No mention is made of possibilities beyond these numbers, and we are left but the one conclusion, that from 4 to 7 horse power must be furnished to the compressor in order to produce a net yield of one horse power in water pumped, and particularly is this discouraging when enterprising advocates of electricity keep emblazoned before us all that imposing array of efficiencies that seem to almost jostle the revered 100 per cent. from its pedestal. Moreover, all this is misleading, for in the proper use of compressed air in pumps we may obtain efficiencies that are more than satisfactory, that, in fact, are difficult to exceed in many instances, and, in this paper, I have tried to make it clear how to practically realize these results.

As an example of the information given by some of the cata-

logues published by builders of compressed air machinery, take an example of 100 gallons of water per minute pumped 200 feet high. What is the quantity of free air and the pressure required in direct acting pumps? Reference is made to Table I, containing extracts from three publications. One hundred gallons per minute, 200 feet high, requires 5 theoretical horse power. Comparing this with the table we find that the efficiencies range from 17 per cent. to 40 per cent., the pressures 11 to 50 pounds, the quantities from 225 to 130 cubic feet of free air per minute and the cylinder ratio from 1 to 1 to 5 to 1. It will also be noted that the pressures required for the same cylinder ratios vary 150 per cent. The pressures given are all receiver pressures or pressures in the main air pipe, which fact is not mentioned, leaving one to draw the conclusion that, no matter what the pressure in the main is, it is only necessary to install a pump with large cylinder ratio and use low pressures.

TABLE I.

FOR 100 GALLONS PER MINUTE. 200 FEET HIGH.

	No. 1.				No. 2.				No. 3.			
Ratio of Air to Water Cylinder.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.	Quantity of Free Air.	Gage Pressure.	H. P.	Efficiency.
1-1	134	11	29	17%								
1.5-1	153	48.8	21	24								
1.75-1	169	36.6	19.5	25								
2-1	181	27.5	16.2	30	130	50	18.2	27%	170	50	23.8	21%
2.25-1	197	22	15	33								
2.5-1	206	17.6	13.5	37	137	40	16.4	30	178	40	21.5	23
3-1					145	33	15.2	33	180	33	19	26
3.5-1					152	29	15	33	185	29	18.5	27
4-1					158	25	13.5	37	205	25	17	28
5-1					176	20	12	41.5	225	20	14.7	34

In mining, compressed air is used for driving rock drills, for hoisting and for pumping, and the average pressures carried in the mains correspond very nearly to the steam pressures formerly used for the same work; 90 pounds gage, independent of altitude, seems to be the standard pressure. This being the case, these tables and pumping data should all be calculated from some such standard basis, with proper coefficients for variations from the standard pressure; and a table, giving the proper cylinder ratios for different heads, using the standard pressures as a basis, would, it seems to me, be more helpful to those who wish to consult tables for a guidance.

In this paper we shall assume 90 pounds to be the standard pressure carried in the mains, and that it takes 20 brake horse power to compress 100 cubic feet of free air to that pressure at sea level with a single stage machine. This is more than is called for by the catalogues, but observations from a great many compressors, of many makes, justify me in this statement, and pressures all along the line will follow the same rule.

There appear to be six general forms of compressed air pumps:

First. Displacement pumps for full pressure only.

Second. Displacement pumps, using expansion.

Third. Direct-acting pumps for full pressure only.

Fourth. Direct-acting pumps, using expansion.

Fifth. Air lift pumps, simple, and combined with displacement chambers.

Sixth. Pumps operated by an independent motor.

The notations employed will be gage pressures unless otherwise specified. Temperatures are expressed in Fahrenheit degrees. The altitude is at zero, that is to say, sea level, and the atmospheric pressure is rated at 15 pounds for the sake of convenience, and 1 foot-gallon, or the work of lifting 1 gallon of water (0.134 cubic feet) to a height of 1 foot, is the unit of work to be performed.

The first general system of pumps, as before classified,—viz, displacement pumps for full pressure only,—appears to be the simplest of all, and is the one which would naturally be first suggested to the mind.

If we have a closed vessel containing water having a discharge pipe, let us say 210 feet high, full of water, connected to its bottom, and we force air at 90 pounds pressure slowly into this vessel, the air will rise to the top of the vessel, and water will be discharged exactly equal in quantity to the amount of air forced in, and $90 \times 0.068 + 1$, or 7, will represent the number of cubic feet of free air required to raise each cubic foot of water. Inasmuch as practice will require a certain additional pressure to give a dynamic head, and there is a certain amount of pipe friction to overcome and some air absorbed by the water, the number 7, before stated, can properly be made 9 cubic feet of free air used to 1 cubic foot of water pumped; or, expressed in foot-gallons, 1 cubic foot of free air, compressed to 90 pounds, will perform $\frac{1}{9} \times \frac{210}{0.134} = 175$ foot-gallons. The 1 cubic foot of free air has received $\frac{1}{5}$ horse power, or 6600 foot-pounds of work expended upon it. One hundred and seventy-five

foot-gallons = $175 \times 8.3 = 1452$ foot-pounds, so that we have here an efficiency of practically 22 per cent., and it will be observed later on that this is better than most ordinary direct-acting pumps will do with cold air as ordinarily used.

The efficiency of this system may be increased 15 per cent. by compound compression; or, if the water to be pumped has a higher temperature than the air, as for instance, in the Comstock, where the water temperature is 120°, the absolute temperature would be 580° and the efficiency would then be $22 \times \frac{580}{520} = 24.5$ per cent., assuming, for this illustration, that the Comstock is at sea level. In this system of pumping the air may be likened to a flexible plunger having a square foot area and making one stroke per minute, and having an actual length of stroke equal to the number of cubic feet of compressed air furnished per minute, diminished by the absorption, leakage, clearance and equivalent quantity necessary to furnish dynamic head and friction, and increased or diminished by the ratio of absolute temperature of air and water. It would be proper to range the efficiency from 15 per cent. to 22 per cent. The chambers of this pump must be submerged, and this fact limits its usefulness. In a sump, or tank, in a mine, and for lifts within range of ordinary compressors, say up to 250 feet, the efficiency obtained will probably exceed that of the ordinary direct-acting pump.

One can readily see that this system exhausts its chambers into the atmosphere at full pressure and all the expansive work contained in the air is lost. A proper compounding of this system, however, will be suggested later on, which will utilize some of this expansion and increase the efficiency materially. Without reflecting, perhaps, engineers have generally discarded this system as too primitive and uneconomical; whereas, in fact, in many instances, it is cheaper by far to install and often would exceed the efficiency of a direct-acting pump.

For handling sewage, or material which would obstruct or destroy pump valves, its utility gives it a desirable place; but, over and beyond this, a well-constructed pump of this type has a right to be properly considered in comparison with ordinary direct-acting pumps.

In pumps of this type there are generally two chambers, so that while one is filling the other may discharge, and thus insure a steady delivery, but frequently single vessels are found adequate. Fig. 1 gives a general idea of this type of pump.

As may be imagined, the inlet and outlet of the compressed air in the original pumps of this class were controlled by floats,

which are unreliable, and which greatly limit the size and shape of the vessels, and the clearance was excessive. The modern type, however, has eliminated all of these uncertainties, and the Merrill Pneumatic Pump Company has an automatic and positive differential controlling valve, situated above the chambers, which are free from floats. Many are in use, and, being free from many of the complications which exist in ordinary pumps, may be classed alongside of ordinary direct-acting pumps where submersion is possible. There is no reason why lifts in two or more stages would not be entirely feasible with this pump.

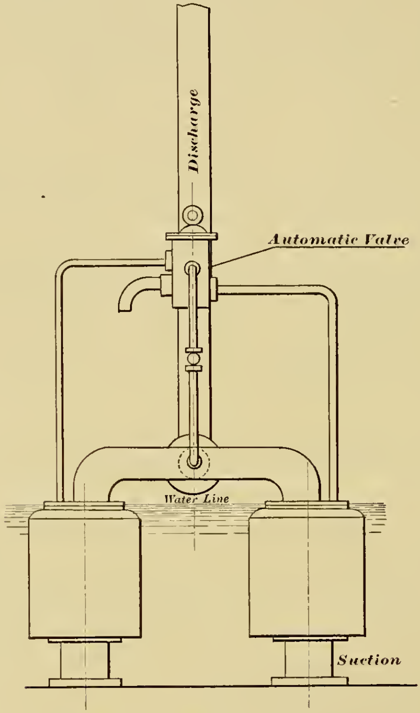


FIG. 1.* MERRILL TYPE OF DISPLACEMENT PUMP.

Class II consists of displacement pumps using more or less expansion. This class of pumps is best exemplified by the Harris system, owned and operated by the Pneumatic Engineering Company, of New York. This system is extremely interesting, simple and economical, and, I have no doubt, would in many cases prove to be the proper installation, especially in mines where a steady flow of water, at reasonable heads, is to be handled.

This system consists in displacing and elevating the water precisely as in Class I, with the difference that while in Class I

* For Figs. 2, 3 and 4, see pages 214, 215 and 216.

the air is immediately exhausted from the water vessels into the atmosphere and all its energy of expansion lost, the compressed air in the latter system, after displacing the water, is allowed to do work in expanding against the compressor piston, and thus, theoretically speaking, all its expansive energy is saved, but practically the manufacturers admit that the losses in leakage and friction are about 15 per cent., a statement which deserves credence.

The action of the pump is as follows: There are two chambers placed within suction limit of the sump, or submerged, as desired. An air pipe leads from the compressor to the top of each chamber. There is a single water discharge connected with both chambers and a single suction. The system is so arranged that while one chamber is filling the other empties, and an automatic switch plays the important part of regulating the admittance and exit of the air. The system is a closed one and only leakage is replaced automatically.

Suppose one of the chambers filled with water. The air is then admitted at such pressure that the water is expelled and the air pipe and chamber are full of compressed air at the pressure of the water lift or slightly more. The other tank has, in the meantime, filled with water. At this point the automatic switch connects the air pipe of the empty chamber with the intake of the air cylinder, and the air pipe of the other chamber with the discharge of the compressor cylinder. It is evident that instantly the air in the first chamber will expand through the compressor and equalize the pressure in the empty air pipe of the second chamber and all clearances. This expansion is lost, but it amounts to but little. The compressor now transfers the air from the first chamber to the second, displacing the water in the second, and the air from the first chamber thus does work upon the air compressor piston in expanding from full pressure to zero. When zero pressure is reached in the first chamber, and if it is not submerged, the compressor continues to draw air from it until the water rises and fills it. At this point the first chamber is ready to be discharged, but if there has been leakage the second chambei has not received enough air to complete its discharge, and this is now supplied by a check valve in the intake pipe which is set to open at a suction pressure slightly above that necessary to draw the water into the chambers. If the chambers are submerged an ordinary check valve will automatically supply any deficiency in the air quantity. The second chamber being completely discharged, the automatic switch reverses and the cycle is complete. Of course

everything depends upon the reliability of the switch, which is placed on the air pipes near the compressor, where the engineer can see its operation and adjust it if necessary. It can be automatically operated in three ways.

First, by means of the suction which occurs in the intake pipe leading to the compressor, when the water is drawn above its outside level in one of the chambers.

TABLE II.

Harris' Compound Pressure Pump.

A. E. Chodzko.

Number of Double Strokes.	Pn Absolute Pressure per Sq. In. after Expansion.	$\frac{Po}{Pn}$	$\frac{Pn}{Po}$	$\left(\frac{Pn}{Po}\right)^{\frac{1}{r}}$	Effective Adiabatic Work of Compression and Delivery. Foot-Lbs.	Effective Isothermal Work of Expansion. Foot-Lbs.	Net Work of Compression and Delivery. Foot-Lbs.
1	88.9	1.18	0.847	0.89	25,704	19,580	6,124
2	73.5	1.39	0.719	0.79	24,768	15,991	8,777
3	64.1	1.63	0.614	0.71	23,509	12,937	10,572
4	54.4	1.92	0.521	0.628	22,824	10,339	12,485
5	46.2	2.27	0.44	0.557	21,270	8,142	13,128
6	39.2	2.66	0.376	0.497	19,960	6,267	13,693
7	33.3	3.14	0.318	0.441	18,360	4,687	13,673
8	28.3	3.7	0.27	0.39	16,517	3,347	13,170
9	24	4.36	0.23	0.349	15,480	2,195	13,083
10	20.4	5.13	0.195	0.31	13,738	1,231	12,507
11	17.3	6.05	0.166	0.28	12,845	401	12,444
12	14.68	7.13	0.14	0.246	11,088	—296	11,384
							141,040

Work of simple compression of 80 cu. ft. of free air to 90 lbs. gage at 6600, 528,000
Work of compound compression " " " " " 446,306

Efficiency of the system referred to compound is therefore, $\frac{446,306}{141,040} = 3.09$

and referred to simple is . . . . $\frac{528,000}{141,040} = 3.75$

Po initial absolute pressure in tank.
final " " in compressor = 90 lbs. g. = 1047 lbs. absolute.
Pn absolute pressure after the *n*th double stroke.
Pa " atmospheric pressure.

$$Pn = Po \left(\frac{V + a}{V + a + v}\right)^n$$

V volume of tank = 8 cu. ft.
a " pipe = 3.24 cu. ft.
v " compressor cylinder = 2 cu. ft.

$Pn = 104.7 \times 0.849\ {}^n/\log.\ Pn = 2.019947 + n \times \bar{1}.928965$

Effective isothermal work of expansion.

$We = 267.87\ Pn - 4233.6$

Effective adiabatic work of compression.

$$We = \frac{v}{r-1}\left[r\left\{P1\left(\frac{Pn}{P1}\right)^{\frac{1}{r}} - Pa\right\} - \left(Pn - Pa\right)\right]$$

Theoretical actual work done in lifting water = 8 × 62.5 × 210 = 105,000 foot-lbs. allowing 85% mechanical efficiency. Real work done = 89,250 foot-lbs.

$$\frac{89,250}{141,000} = 63.3\%$$

Second, by a mechanism that will throw the switch at some assigned number of strokes of the compressor, the proper number being that which will empty one chamber and fill the other.

Third, by an electrically-controlled mechanism, the circuit being made and broken by a pressure gage on the intake of the compressor or by a float in one of the chambers.

In Figs. 3 and 4 we have diagrams and data supplied to the writer by the Pneumatic Engineering Company, which will be interesting to those who care to investigate this extremely interesting and economical method of pumping by compressed air.

Table II gives a problem of pumping under 90 pounds pressure, which shows in detail the change of work on the air compressor piston during the progress of changing the air from one water chamber to the other. It will be noted that the net work is even less than the full pressure work at 90 pounds pressure, thus showing that the compression work is practically eliminated, and that 90 pounds pressure can be transferred from one receiver to the other at less than one-third of the power required to fill a receiver at 90 pounds pressure. Consequently this system should be at least twice as economical as the regular displacement system. The disadvantage is that it requires an independent plant and a double set of air pipes. I have no hesitancy in placing the efficiency at from 60 per cent. to 70 per cent., and I consider it a very desirable system for mine station pumping.

DIRECT-ACTING PUMPS.

The ordinary direct-acting pump is the best known of all power pumps and is the typical example of a motor-driven displacement pump. Its efficiency suffers on account of its large clearance, its apparent inability to realize full stroke and the ill-advised selection of cylinder proportions. In general it is given a mechanical efficiency of 65 per cent. It is not a perfect displacement pump, because the valves are generally so arranged as to cut off just before the completion of the stroke, in order to exhaust the inertia of the moving parts by the time the stroke is finished, and this gives a slight expansion in the cylinder, but this expansion may be neglected in general and the pump put in the displacement class.

If a pump uses full pressure only, it is evident that the more full pressure its compressor diagram shows, the greater will be the efficiency of the system. The lower the air pressure the less is the compression work and the greater the proportion of full pressure work; consequently the lower the pressure the more efficient

is the system. This really refers to the compressor and not to the pump, for the pump works the same whether it receives air at 10 pounds pressure from the compressor or whether the air has been expanded from a receiver having a higher pressure, provided the temperatures are constant.

If, then, we look for the best efficiency from direct-acting pumps, we must put in an independent compressed air system and

TABLE III.

Press. of Air.	Volume. Cox.	H. P. Cox.	Ratio Comp. Referred to 90 Lbs.	Adiabatic Increase Ratio.	Practical Increase Ratio.	Increased Volume.	H. P. at 90 Lbs.	Eff. Cox.	Eff.
20	113	8.4	3	1.37	1.26	142	28.6	30	9
25	108	9	2.6	1.32	1.22	125	25	27	10
30	97	9.6	2.3	1.27	1.19	115	23	26	11
35	93	10.1	2.1	1.24	1.17	108	21.5	25	11.5
40	89	10.6	1.9	1.2	1.14	101	20	24	12.5
45	87	11.2	1.7	1.16	1.12	97	19.7	22	12.6
50	85	12	1.6	1.14	1.11	94	19.1	20.5	13
55	82	12.5	1.5	1.12	1.09	89	18	20	14
60	80	12.6	1.4	1.1	1.07	85	17	19.8	14.7
65	79	13	1.31	1.07	1.06	84	16.8	19.3	15
70	78	13.4	1.24	1.06	1.05	82	16.4	19	15.3
75	77	13.6	1.17	1.05	1.04	80	16	18.5	15.6
80	76	14	1.1	1.04	1.03	78	15.6	18	16
85	75	14.5	1.05	1.02	1.02	76	15.2	17.5	16.5
90	74	14.8	1	1	1	74	14.8	17	17
1	2	3	4	5	6	7	8	9	10

10,000 foot-gals. = 83,000 foot-lbs. = 2.5 H. P. theoretical.

EXPLANATION OF TABLE.

Col. 1—Gage pressures in air cyl. of pump.
Col. 2—Is the volume of free air required, calculated from Cox's computer.
Col. 3—Horse power corresponding to above volume, calculated from same computer.
Col. 4—Ratio of gage pressures in Col. 1 to 90 lbs. Standard Mining Pressure.
Col. 5—Adiabatic temperature. Ratios corresponding to pressure ratios in No. 4.
Col. 6—Are practical temperature ratios, being 70% of No. 5.
Col. 7—Is Col. 2 multiplied by Col. 6.
Col. 8—Is H. P. calculated for No. 7 by Cox's computer 76.
Col. 9—Are percentages of Col. 3.
Col. 10—Are percentages of Col. 8.

carry a low pressure. We can hardly imagine that this would be generally done and consequently we must count on the standard pressure of about 90 pounds for our economies and proportions.

After comparing the various tables of compressed air quantities for direct-acting pumps it appears that the calculations of William Cox are the most reliable, and they agree very nearly with

practical results that I have noted. He, however, like the others, considers that the pressure used by the pump is receiver pressure. The following are his principal formulæ, based on 100 feet of piston speed. Other speeds will naturally be in proportion:

Diameter of water cylinder $= 0.54 \sqrt{\text{gallons raised}}$.

$$(\text{Diameter of air cylinder})^2 = 0.5 \times \text{head} \times \frac{(\text{diam. of water cyl.})^2}{\text{gage pressure}}$$

Volume of free air $= 0.63 \times (\text{diam. of air cyl.})^2 \times (1 + 0.068$ gage pressure), and in general, without regard to any factors but quantity, head and pressure, we have

$$\text{Volume of free air} = \frac{0.093 \text{ foot-gallons} \times (1 + 0.068 \text{ gage pressure})}{\text{gage pressure}}$$

In using these formulæ it must always be borne in mind that the pressures given are receiver pressures; that is to say, that the compressor furnishes air to the mains at the pressures called for in the tables, and, if any higher pressures are carried in the mains, such as 90 pounds, and the air cylinder of the pump is so large that the air is wiredrawn to it, then the quantities of compressed air given should be multiplied by a constant, such as given in Column 6, Table III, when the pipes are short between the main and the pump, as occurs generally in a shaft.

The constants in Table II are simply about 70 per cent. of the ratio of the absolute temperatures due to the expansion of the air from 90 pounds to the pressures indicated in the tables, and the horse power will not be the power required to raise the pressure from atmosphere to the working pressure, but always that required to deliver it into the mains. This fact makes sorry work for efficiencies.

Inasmuch as most pumps are in the shaft near the main, a very short pipe connects them to the main, and the air is expanded through this short pipe to the pump for pressures less than that in the main. This expansion reduces the temperature of the air entering the pump to quite a marked degree, but not by the theoretical amount due to the pressure drop, for some heat from external sources is supplied, and also from the friction of wire drawing.

While I have made no experiments on this subject I have assumed that less heat would be given to this expanding air than a good water jacket would take out of the air during compression, and I have assumed the temperature to drop 70 per cent. of that due to the pressure drop. This reduces the air volume and adds to the quantity consumed by the pump, and consequently lowers its efficiency.

It would be a good practice to let this cold air gain normal temperature before reaching the pump cylinder, and this can be done by passing the water being pumped into an enlargement in the discharge pipe, within which is a coil through which the air is passed, but if no such device is used and if the air pressure in the mains is 90 pounds, we shall find that Table III expresses about the real condition of affairs for a pumping effort of 10,000 foot-gallons.

Conclusions from Table III:

First. The lower the air pressure in the main, with cylinders designed properly, the greater the efficiency, reaching as high as 30 per cent.

Second. The efficiency drops immediately if the air is expanded through the throttle into an air cylinder which requires less pressure than the main.

Third. At standard mining pressure of 90 pounds the efficiency is about 17 per cent. with properly designed cylinders, and probably drops as low as 12½ per cent. in pumps where "just one turn of the valve is open."

Fourth. Very little loss occurs in using pressures within 10 per cent. of the pressures in the main, which is ample to impart proper dynamic head to pump.

If compound compression should be used, then the efficiencies mentioned can be increased 15 per cent., and they will range then as high as 34.5 per cent. for low pressures and from 19.55 per cent. to 14.5 per cent. for standard mining pressures.

If the air is reheated, so that the pump cylinder receives it at 300° F., and if no account is made of the cost of reheating, then the efficiencies for low pressures and simple compression will be 42 per cent., for compound compression 48 per cent. and for standard mining pressures, for simple compression, 24 per cent. to 17.5 per cent. and for compound compression 27½ per cent. to 20 per cent.

According to the above table, at standard mining pressure, the efficiency, using cold air, is 17 per cent. at maximum. According to our statment, if 20 horse power produce 100 cubic feet of free air compressed to 90 pounds, 1 cubic foot will cost 6600 foot-pounds of work. Seventeen per cent. of this would be 1122 foot-pounds of useful work that the one cubic foot of free air would perform. Eleven hundred and twenty-two foot-pounds is equal to 135 foot-gallons.

I have measured the exhaust of many pumps using air at from 80 to 90 pounds, and I have found their work to be approximately 135 foot-gallons for each cubic foot of air. I have used this figure

in all my calculations for ordinary pumps, properly proportioned. Thus, to lift 200 gallons a minute 200 feet high would be 40,000 foot-gallons. This, divided by 135, would require 300 cubic feet of free air compressed to 90 pounds, which in turn requires 3×20 or 60 horse power to produce it. If compound compression be used, I increase the 135 foot-gallons by 15 per cent. and call it 155 foot-gallons; and, if reheating is used, in either case, I increase the 135 by the ratio of absolute temperature which I am satisfied the pump receives.

The efficiency of the direct-acting pump is shown in the diagram, Fig. 5, as follows:

With a simple compressor the M. E. P. of compression is a little more than the M. E. P. adiabatic, say 40 pounds. This cor-

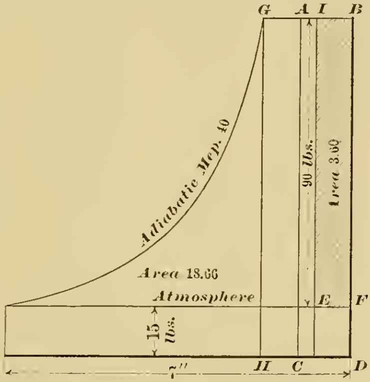


FIG. 5. DIAGRAM OF ORDINARY DIRECT-ACTING PUMP.*

responds to an area on this card of M. E. P. $= \frac{\text{area} \times \text{spring}}{\text{length of card}}$; $40 = \frac{A \times 15}{7}$ or $\frac{280}{15} = 18.66$ square inches. The adiabatic volume of G, B, D, H, shrinks to A, B, C, D, before arriving at pump. The pump having a mechanical efficiency of 65 per cent., the volume I, B, E, F, is all that really does useful work. That area is $0.6 \times 6 = 3.6$ square inches. $\frac{3.6}{18.66} = 19$ per cent., which compares nearly with our other figures.

We found simple displacement pumps, Class I, giving 175 foot-gallons of work, and direct-acting pumps, Class II, giving

*In this and the following diagrams, atmospheric pressure = 15 pounds. Pressure scale, 1 inch = 15 pounds. Receiver pressure = 90 pounds or 7 volumes. The diagrams are here reduced to ¼ size. The adiabatic area of the diagram is taken at 18.66 sq. in., or 20 H. P. per 100 cu. ft. free air compressed to 90 pounds. Compound compression area = 16 sq. in. Isothermal area = 13.44 sq. in.

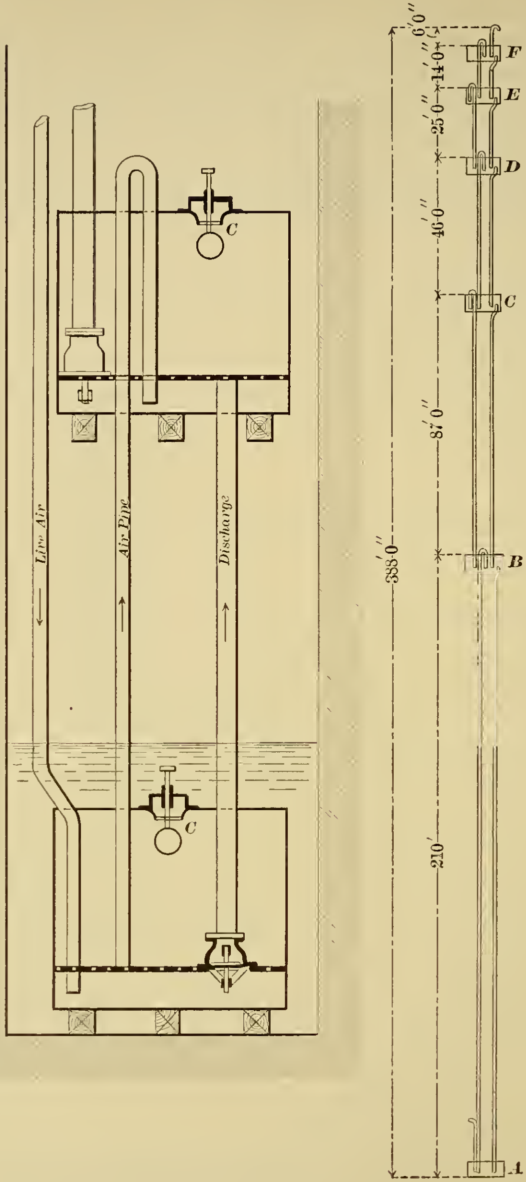


FIG. 6. MULTI-CHAMBER LIFT WITH EXPANSION.

135 foot-gallons of work. This might be anticipated, because in Class I the air is used isothermally throughout, the pressure is always exactly what is necessary, the clearance is small and there are no mechanical movements to overcome.

Referring again to the Table III, and remembering that we have assumed 90 pounds as our standard pressure in the mains, we note how serious a loss we would entertain if we used a pump having an air cylinder so large that the working pressure was 20 pounds. One not skilled might expect to get 30 per cent. efficiency, but would really get about 10 per cent., or just 300 per cent. out of the way, and this justifies the remark that I have heretofore made that these catalogue tables are misleading. Except for extremely small quantities and for sinking pumps, I cannot justify the use of simple direct-acting pumps for compressed air use.

Simple displacement pumps, mentioned in Class I, can be made to use the air with at least partial expansion, and I suggest the following for your consideration and experiment. It occurred to me while searching for a cheap and economical means to do some air pumping. We will take the same problem of work at 90 pounds pressure. In order to make the problem simpler I have made it purely theoretical, and we can supply whatever efficiency coefficient we deem appropriate.

Suppose we have six equal-sized tanks, A, B, C, D, E, F, Fig. 6, arranged one above the other at distances we shall shortly determine. Suppose tank A submerged in a sump, and an air pipe conducting compressed air at 90 pounds to this tank. From each tank to the one above there is an air pipe leading from the bottom of the lower tank to the top of the upper one, as shown. From each tank to the one above there is a water discharge pipe leading from the bottom of the lower one to the bottom of the upper one, as shown, and having a check valve on its lower end to keep it full of water. From tank F the discharge is to the surface G. On each tank is a check valve C, opening the tanks to atmosphere whenever the pressure falls to atmosphere within the tanks and closing them whenever the water rises against them. Now, if tank A be full of water, and air at 90 pounds be admitted, the water will be displaced into the tank B a distance of 210 feet, just as it did with the Merrill pump, but when the water is all discharged from A, and just before the water discharge pipe is uncovered, the air pipe leading to tank B is uncovered and the air passes up into tank B, expanding against the water and pushing it up into tank C a distance equal to one-half the absolute pressure of 90 pounds. This must be so because, tanks A and B being equal, the pressure becomes 37.5 pounds in both of them when they contain air and not water, so now we have the water in C at 87 feet above B, and in a similar manner it will be pushed into D and E and F and finally out at G distances 46 feet and 25 feet, 14 feet and 6 feet,

respectively, corresponding to $\frac{1}{3}$ and $\frac{1}{4}$, $\frac{1}{5}$ and $\frac{1}{6}$, the absolute pressures of 90 pounds. When D is empty the whole system is full of expanded air at 2.5 pounds, at which pressure it exhausts into the atmosphere. No mechanism is necessary except the one small valve mechanism, similar to the Merrill device, and this admits air into A at proper intervals. The rest of the tanks take care of themselves. If fine economy is not required, only the water pipe need connect the tanks, the air pipe may be eliminated and also the check valves in the water pipes, and the air will drive the water from tank to tank and finally escape. The check valves C will then drop open and air may be again admitted at A. The water pipes, being always full, do not form clearance. It matters not how much water is left in the bottom of the tanks, so long as they are all alike. That does not form clearance, and, so long as the tank is full before the valve switches, there is practically no clearance. The air, as admitted to the tanks, is made to bubble up through the water in small bubbles through a false bottom, and thus the expansion is made isothermal.

The system can be made double, or in any number of units, so that the discharge may be constant. The objection to the system for shaft work is in the space required for the tanks, which might not be objectionable in some places. For outside pumping it would be efficient and easy to install. As to economy, not much of a calculation is necessary to show that if the Merrill pump did 175 foot-gallons of work with one cubic foot of free air at 90 pounds, and lifted the water 210 feet, this system, with the same air, will do $175 \times \frac{388}{210}$ or 320 foot-gallons, because it has lifted the water $87 + 46 + 25 + 14 + 6$ feet, or 178 feet, further, or a total of 388 against 210. This makes the efficiency $22 \times \frac{388}{210}$ or 40 per cent., quite an advance over the efficiencies of direct-acting pumps.

Another peculiarity is that although 90 pounds pressure corresponds to 210 feet head, it is lifting water 388 feet, so that the cylinder ratios, as it were, are inverse.

If we now study the diagram, Fig. 7, made up from the action of this pump, and allow that the expansion is isothermal, we have A, B, D, C, as the original volume at 90 pounds in the first tank. This expands to E, F, D, I, in the second tank, and so on to atmosphere after leaving the sixth tank. It is evident that the triangular areas A, E, T, etc., six in all, are the expansion losses, but when it is considered that these expansions furnish the dynamic head that overcomes the element of time and pipe friction, we see that, even

if there is loss, it is necessary, and if the air had expanded along the isothermal line we would have been obliged to add to our initial pressure and quantity to overcome these resistances. Consequently, as a pump, it has a high efficiency, for it utilizes about all the expansion energy of the air. To calculate it from the card without planimeter, we have as follows:

The card being 7 inches long, 7 atmospheres high and 1 atmosphere to the inch, we have

M. E. P. isothermal 28.89 pounds.

We know that $\frac{\text{area of card} \times \text{spring}}{\text{length}} = \text{M. E. P.}$

Therefore, $\frac{\text{M. E. P.} \times \text{length}}{\text{spring}} = \text{area}$, or in the case $\frac{28.89 \times 7}{15} = 13.41$ square inches.

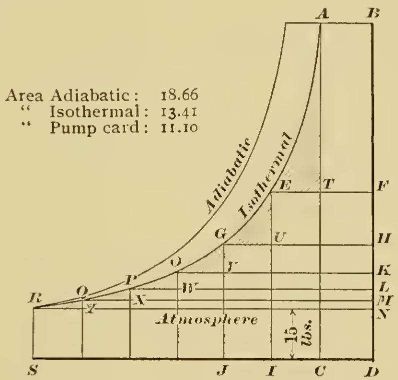


FIG. 7. DIAGRAM OF MULTIPLE DISPLACEMENT PUMP USING EXPANSION.

The card being lined to square inches it is easy to add up the effective area, and we find it to be $\frac{7}{2} + \frac{7}{3} + \frac{7}{4} + \frac{7}{5} + \frac{7}{6} - 7 \times 1 - 0.05$, the latter being the area R. Q. Y., or $18.15 - 7.05 = 11.1$ net area. The curve area being 13.41, the efficiency of the pump $= \frac{11.1}{13.41}$ or 82 per cent., and, for the efficiency of the system with simple compression, we have as before, adiabatic area 18.66. The work area 11.1 divided by this, gives 59 per cent. efficiency for the system. Allowing for it the same ratio of losses,—viz, 7 to 9, as we did the Merrill, we have $59 \times \frac{7}{9} = \frac{413}{9} = 45$ per cent. net, nearly the same figures we had before.

With compound compressor I should look for 50 per cent. efficiency in this system, and I hope the suggestion will prove interesting enough to encourage some one to try it.

We come now to what I deem the most interesting and useful class of compressed air pumps,—viz, the motor displacement pumps, using more or less expansion, otherwise called compound or multi-cylinder pumps.

COMPOUND OR MULTI-CYLINDER PUMPS.

Judging by results, these are very little understood, even by the people who build them, so far as their use of compressed air is concerned. The general idea has been that if the expansion of air produces such low temperatures that it frequently freezes a simple pump to a stop, it would be unwise to try further expansion in a compound pump, and consequently the compressed air users have practically avoided multi-cylinder pumps.

I hope to show that even a triple or quadruple-cylinder pump may be operated not only safely but economically, with no further addition of heat than that supplied by the water itself.

First, however, I shall speak of the phenomenon of freezing. This is a very simple matter, easily explained and easily remedied. The compressed air, being used at full pressure in the pump cylinder, is thus exhausted, and, doing its expansion work within and about the exhaust ports, reduces their temperature until ice is formed in the exhaust and finally closes the opening. I believe the action to be cumulative and on the principle used in making liquid air, for I have noticed that when once the pump cylinder becomes quite cold the choking proceeds more rapidly. The colder the air previous to exhaust, the colder will be the exhaust, which in turn makes the cylinder colder and thus the cumulative action goes on rapidly. I have heard that makers have advised short ports and conically tapered ones, with no threads, to avoid freezing. I have seen pumps with steam injected, pumps with fires under them and pumps submerged in a tank of water, all in order to avoid the freezing. Where it is not desirable to reheat pumps with steam or hot air, there are, to my mind, two simple methods of avoiding freezing; first, tap the discharge main with a quarter-inch pipe, draw down the end of this pipe until the hole is of the size of a knitting needle, introduce this small pipe well into the exhaust of the pump and let a small amount of water continually discharge therein. It will keep the temperature of the metal above freezing point and thus prevent freezing. The loss of water is very small. A pump doing 10 horse power actual work, using 250 cubic feet of free air weighing about 20 pounds, would use, I should judge, about 10 to 12 pounds of water per minute, or $1\frac{1}{2}$ gallons would be ample for the work. Or, if it is not desirable to waste this water,

exhausting through a coil of thin pipe placed in a chamber, through which the suction or discharge water circulates, will furnish to the expanding air heat enough to prevent freezing.

The second method for preventing freezing would be to use compound pumps, properly arranged. This, you will note, is exactly contrary to the generally accepted practice. Inasmuch, however, as a compound pump is in no wise different from two simple pumps having the same sizes of cylinder and using the same pressures, and inasmuch as the temperature drop on the initial cylinder is about one-half that of an equivalent simple pump, it is evident that it will not freeze, and, if the exhaust be carried through a copper coil over which the water being pumped flows freely, the air will become of about the same temperature as the water, and it will, thus reheated, pass to the compound cylinder at the same temperature as it entered the initial cylinder, and, passing from this cylinder, it will exhaust without freezing, and the pumping economy will be advanced 30 per cent. or more. Each cylinder would thus dispose of about half the temperature. If, however, no water heater was introduced between the cylinders, the initial cylinder would discharge the air at large temperature drop into the second cylinder. This gives a cumulative effect to the cooling at the exhaust of the second cylinder and rapid freezing up would result. This has led every one to believe compound pumps impractical for cold air, but by the introduction of the water-heated coil between the cylinders, without cost for heat units, the compound pump will not freeze and will be more economical.

It is evident that the lower the ratio of pressures the less the ratio of temperatures and consequently the less liability to freezing.

To return now to the compound, direct-acting pump.

Compound pumps of the better class can be given a mechanical efficiency of 70 per cent., which covers losses in the air and water cylinders and the friction in the pipes, with an allowance for dynamic head. Their economy depends upon the character and amount of the reheating applied to the air.

There are four general classes:

1. Reheating with the water pumped.
2. Extraneous heating before the initial cylinder.
3. Extraneous heating before the compound cylinder.
4. Extraneous heating before both cylinders.

In the first class for mine pumping the temperature of the water may be generally assumed to be 60°, and the heater is a shell filled with copper tubes and preferably made a part of the suction pipes, the water flowing around the tubes through which the air is

exhausted from the first cylinder to the second. A steam heater, of the Wainwright type, gives the idea, and about one square foot should be allowed to every five cubic feet of free air. As stated before, its action is to restore to normal temperature the compressed air exhausted from the initial cylinder, thus delivering it to the second cylinder at the same temperature as to the first, just reversing the action of the inter-cooler during compression, and, inasmuch as the cylinders use the air at practically full pressure, the expansion takes place in the reheater. The diagram, Fig. 8, shows what takes place as far as economy is concerned. B, C, D, E, is taken at 70 per cent. of the volume furnished to the pump to cover the mechanical efficiency. This expands 2.65 times (when the initial pressure is 90 pounds) in the reheater and F, E, H, G, is the volume given the second cylinder. The areas $= 0.7 \times (7 - 2.65)$

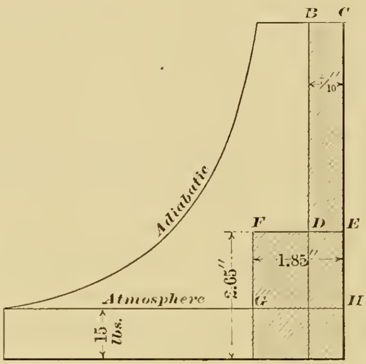


FIG. 8. DIAGRAM OF COMPOUND PUMP. WATER REHEATED.

$= 0.7 \times 4.35 = 3.045 + (1.855 \times 1.65) = 3.06 = 6.1$ square inches. It will be noted that the work in both cylinders is alike— $\frac{6.1}{18.66} = 32.7$ per cent. against 19 per cent. that we figured by the same method for the simple pump. This is a very large gain and it costs nothing to maintain it, the first cost of the heater being small. I cannot conceive of a more forcible argument in favor of compound pumps.

For compound compression this efficiency will be increased to 37.5 per cent. If our simple pump did 135 foot-gallons of work then this style of compound will give $135 \times \frac{32.7}{19} = 232$ foot-gallons for a cubic foot of free air compressed to 90 pounds gage.

In compound pumps, where we have extraneous heating previous to the admission of the air into the initial cylinder, let us suppose the heating to be 283° F. This will be sufficient to increase the volume from $\frac{7}{10}$ in our former example to 1, in other words, to off-

set all the mechanical losses in the pump, and the initial cylinder will be full of air at 90 pounds and 743° absolute or 283° F. When the air is exhausted from this cylinder into the low-pressure cylinder there is an expansion ratio of 2.65 between the cylinders, provided there is a small receiver between the two cylinders; the temperature will drop a ratio of 1.32, or, considering the losses of radiation, will reach 60° again and will enter the low-pressure cylinder in precisely the same condition as in the former case, and with the same volume. Consequently we have no gain in this way of reheating, except for the initial cylinder, unless the heating be carried so that the cylinder will receive it at more than 283°, which might not be practical. Referring to our last diagram, Fig. 8, we note that we have added the area I, B, D, J, to our economy diagram, and the diagram, Fig. 9, is the result. The area of useful

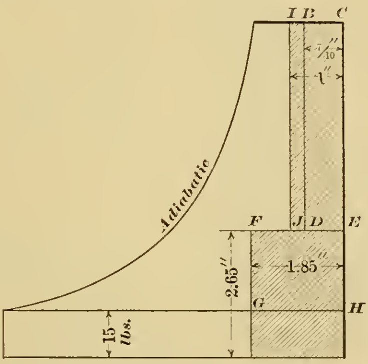


Fig. 9. Compound Direct-Acting Pump. Reheated to 300° before the Initial Cylinder.

work will be $1 \times 4.35 + 3.06 = 7.41$, and, the compression area being 18.66, the efficiency is $\frac{7.41}{18.66} = 40$ per cent., against 32.7 per cent. in the former case, and for compound compression this will be 46 per cent., and the foot-gallons of work will be 280 for each cubic foot of free air compressed to 90 pounds gage.

If, however, there be a reheating between the two cylinders to 283° F., then the volume entering the low-pressure cylinder will be increased about 1.43 per cent., and, instead of 1.85 per cent., as on the former diagram, it will become 2.65 per cent. and will occupy the area shown as K, E, H, L in diagram, Fig. 10.

The useful area in this card will be $4.35 + 4.35 = 8.7$. It will be noted that the work is the same in both cylinders and the final efficiency will be $\frac{8.7}{18.66} = 46$ per cent. If compound compres-

sion is used it will become 53 per cent., and the foot-gallons of work it will perform will be 326.

It will be noted that the points K and L are on the isothermal curve, which means that we have utilized completely the full pressure work within the isothermal curve, using two expansions, and if three cylinders be used and proportioned by the same rule, we make a still further gain, as per diagram, Fig. 11, giving 54 per cent. for simple compression and 62 per cent. for compound compression. The foot-gallons of work it will perform will be 383. These figures are perfectly practical and rather under the mark.

It is easy to see that more cylinders would add to the economy, but, inasmuch as three are practical and four are too many, we may as well stop here. For higher economy on this system the reheating must be carried higher, inasmuch as 400° is perfectly

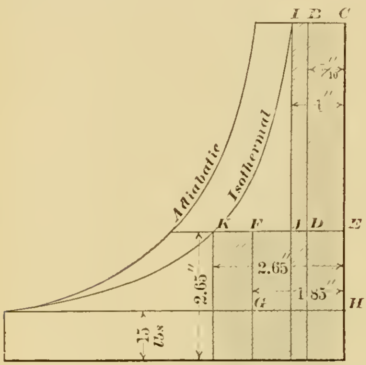


FIG. 10. COMPOUND DIRECT-ACTING PUMP. REHEATED TO 300° BEFORE INITIAL AND LOW-PRESSURE CYLINDER USING FUEL PRESSURE ONLY.

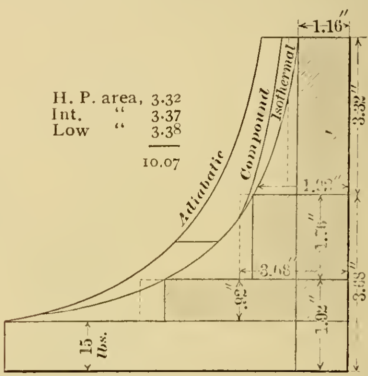


FIG. 11. THREE-CYLINDER REHEATED COMPOUND PUMP. USING FULL PRESSURE ONLY.

practicable and as easy to obtain as 300°. This would add 16 per cent. to our area and give 63 per cent. and 72 per cent., respectively; our foot-gallons of work would be 444 foot-gallons, and the dotted lines on the diagram will represent the shape of the card and show how it may extend over the isothermal curve. This I call the practical limit.

We have seen that a cubic foot of free air at 90 pounds pressure will perform, under proper conditions, 444 foot-gallons of work. This is 3685 foot-pounds, which may be decreased 5 per cent. on account of the cost of reheating, making net 3500 foot-pounds of work. On account of the 70 per cent. efficiency of the compound pump, we gave it one cubic foot of free air in our calculation and called it $\frac{7}{10}$. The air itself must be given credit for

this, and if, in the 70 per cent. efficiency pump, it did 3500 foot-pounds of work, it really was yielding up $\frac{3500}{70}$ or 5000 foot-pounds.

It takes 5600 foot-pounds of work to compress this air in a compound compressor. The air has therefore shown, in its work, an efficiency of 90 per cent. as a motive power, at 90 pounds pressure in triple, compound, direct-acting pump cylinders, triple reheated to 300°, a result entirely different from what we are in general almost forced to believe.

Figs. 12 and 13 show two actual cards illustrating the principle of full pressure working. It will be noted that the expansion shown is small, and, if the reheater had a little larger capacity, the diagram would be rectangular.

JULY 30, 1900. TEMPERATURES.

Between heater and throttle,	248°	Air gage,	70 Lbs.	
" throttle and H. P. cylinder,	200°	Water gage,	160 "	No. 13.
Exhaust H. P.,	78°	Stroke,	14½ Lbs.	W. H. P. H. E.
Inlet L. P.,	289°	Revs. p. m.,	24	Spring 40.
Exhaust L. P.,	134°	H. P. cylinder,	16 inches.	

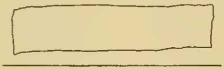


FIG. 12.

JULY 30, 1900. TEMPERATURES.

Between heater and throttle,	229°	Air gage,	72 Lbs.	
" throttle and H. P.,	196°	Water gage,	160 "	No. 11.
Exhaust H. P.,	76°	Stroke,	14½ Lbs.	W. L. P. P. E.
Inlet L. P.,	285°	Revs. p. m.,	23	Spring 16.
Exhaust L. P.,	133°	L. P. cylinder,	25 inches.	

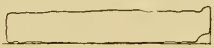


FIG. 13.

Unfortunately, at the time these cards were taken, the pump was throttled, and the air was drawing from 70 pounds to 50 pounds, so that its efficiency is diminished. The pump, however, was delivering 396 gallons per minute 390 feet high, consuming 600 cubic feet of free cold air at 50 pounds pressure, and giving 250 foot-gallons per cubic foot of free air, at 50 pounds pressure, with an efficiency, referred to 50 pounds, of 65 per cent.; referred to 70 pounds, of 52 per cent.; the total energy, from 70 pounds to 50 pounds, being lost in the throttling of the pump. It illustrates, however, our proposition and confirms our figures.

It seems to be generally believed that the best result, in compound pumps using compressed air, is obtained when we get as much expansion within the cylinders as is possible, and the highest efficiency which could be obtained in this manner would be when there is no drop whatever between the high and low-pressure cylin-

der, and the air is expanded to atmosphere in the low-pressure cylinder as shown by the ideal card, Fig. 14. This would require heating to 454° F., the temperature of adiabatic compression.

The practical action of a once reheated compound pump is as follows: The air enters the high-pressure cylinder, we will say, at a temperature of 200°, and at 100 pounds pressure. This air operates at full pressure throughout the whole stroke, and there is no drop whatever in its temperature; the exhaust valve opens, there being a considerable space between the high and the low-pressure cylinder (in the shape of pipes and clearances, and, if there be an intermediate reheating, in the additional space for the reheater); the pressure immediately drops, we will say, to 50 pounds, and the temperatures suffer in adiabatic proportion to the absolute pressures.

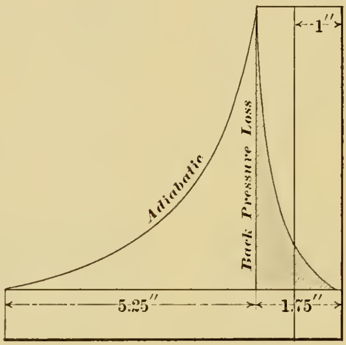


FIG. 14. IDEAL COMPOUND CARD. AIR HEATED TO 454° F.

This expansion from 100 pounds to 50 pounds does no work whatever and is entirely lost. The volume of air shrinks in proportion to the absolute temperature, and then passes into the low-pressure cylinder and immediately commences to expand therein as the piston commences to move. Here will be a case of adiabatic expansion, for the temperature in the cylinder must drop as the pressures drop, and the expansion takes place adiabatically to the end of the stroke, where, with a terminal pressure, we will say, of 10 pounds, it drops out into the atmosphere at a temperature probably a few degrees below that of the atmosphere.

The M. E. P. of the expansion from 50 pounds down to say 10 pounds is not a very large proportion of the total possible expansion work of the air from 100 pounds down to 10 pounds, and this is still further reduced by the fact that, while we have the expansive work in the low-pressure cylinder, we have also a variable

back pressure on the high-pressure cylinder, which means an unequal load on the piston and a consequent variable speed.

An attempt has been made to realize the work of expansion between the two cylinders; but, owing to the natural mechanical construction of the pump, it is impossible to realize but a small part of it, and I believe the correct method of operating these pumps is to do all the expanding between the cylinders, restore the volume by reheating and use only full pressure in the cylinders. We thus avoid any temperature drops in the cylinders and we have a constant pressure therein, and a consequent constant speed and constant back pressure.

In a compound pump the proportion of the low-pressure cylinder to the high will be larger than what is in use at present, for the low-pressure cylinder will be operated at its terminal pressure throughout the stroke. In other words, the card will be rectangular.

We believe that, instead of using two cylinders, with a greater ratio of area, it would be better to use three cylinders and so to proportion the area between them as to have the terminal pressure desired. In this way the drop between the cylinders will be small, and the opportunity to take advantage of double heating considerable. The ideal situation, theoretically speaking, would be where a large number of cylinders are in operation, one after the other, with only a sufficient drop between them to give them the necessary dynamic head. The combined card would then represent a series of steps considerably overlapping any possible card that could be made by an adiabatic expansion.

If it were possible ordinarily to expand without drop from the initial pressure, there would be no criticism of ordinary methods; but, inasmuch as a drop must be made, the question naturally arises, Is it not better to make the complete drop and take advantage of the situation when the drop occurs, an advantage which is neglected when a combination is made of half drop and half expansion? The Comstock offers every possible opportunity for this kind of a proposition. The temperature of the water is 120°, and the pump, the water, the intercoolers, the air and everything will always be at that temperature, except if the air expands in any one of the cylinders. It is well known that air is such a poor conductor of heat that no matter if the cylinder walls be hot it will drop its temperature in expanding. In other words, the expansion in the cylinders would be adiabatic; whereas, if a complete drop is made and the temperature restored between the cylinders, and if then it is used in the cylinders at full pressure throughout the

stroke, it will approach nearer an isothermal expansion for the air than any other kind of a practical method with direct-acting pumps.

The economical expansion of air must ever be the exact reverse of the economical compression of air, and the ideal air compressor would be one of many stages with a small rise in pressure between each two stages, just sufficient to keep the air moving, and an intercooler to take out this small increment of heat between every two stages, making a practically rectangular card between each two. The natural reverse of this, for the economical expansion of air, would be a multitude of cylinders, with sufficient drop between each two to maintain a circulation of the air, and a reheater between each two cylinders, making a practically rectangular card for expansion in each cylinder.

As illustrating the principle which I advocate, attention is called to Fig. 15, showing two diagrams from a compound pump, reheated before the initial cylinder to 165° F. This pump is doing fair work, raising 450 gallons per minute 424 feet high. It receives air at 63 pounds gage and 165° F., takes air at practically full

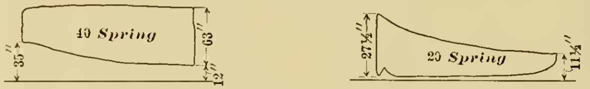


Fig. 15. Cards from Compound Pump 14″ + 24″. Cylinder Heated to 165° before Initial Cylinder.

stroke, exhausts into the pipe connecting the two cylinders, drops to 35 pounds gage and gradually expands as back pressure against the high-pressure piston, until 12 pounds is reached. The low-pressure piston receives the pressure at 27½ pounds and the air is expanded to 11.5 pounds. It then exhausts, against 2 pounds back pressure, into the atmosphere.

Assuming the volume of the high-pressure cylinder to be one cubic foot and having no clearance, etc., inasmuch as we are about to make a comparative statement, we find that the work on the high-pressure piston is 6797 foot-pounds and on the low-pressure piston 1581 foot-pounds, a total of 8378.5 foot-pounds.

Let us consider another method. If we use the pressure at 63 pounds on the same high-pressure piston and let the exhaust make a complete drop to 11.5 pounds, the work on the high-pressure piston will be 7416 foot-pounds, and if we reheat in the receiver to 165° and construct the low-pressure cylinder of such a size that after receiving the air at 11½ pounds it will exhaust at 2

pounds, thus preserving the relation of the previous problem, the cylinder ratio will be 3.06 and the work on the low-pressure cylinder becomes 4186 foot-pounds, making a total of 11,602 foot-pounds, or a gain of 40 per cent. again.

Suppose we make it a triple-cylinder pump, make each cylinder do the same work, reheat to 165° before each one and use the same 2 pounds back pressure, then the initial cylinder will take the pressure at 63 pounds and do 4550.4 foot-pounds, the intermediate will take the pressure at 31 pounds and do 4450.4 foot-pounds of work, and the low-pressure cylinder will take the pressure at 12.4 and do 4550.4 pounds and will exhaust at 2 pounds back pressure, making a total of 13,651 foot-pounds, or a gain of 64 per cent.

The pump is now doing about 220 foot-gallons of work. If we add 64 per cent. to this we will have 360 foot-gallons. We claimed 383 in our former diagrams, for higher reheating, which checks results quite nicely.

The cylinder ratio in the foregoing will be, for equal work in the cylinders, the cube root of ratio between initial and absolute pressures, 1.7, making the pressure 63, 31 and 12.4, respectively. The atmospheric pressure was 13.5 pounds.

Your attention is particularly called to the difference between steam and air practice, for here is a triple expansion, so called, operating with 63 pounds initial pressure properly. The number of cylinders that could be properly used will have to be determined by practice, the limit being when their mechanical deficiency offsets their economy.

There are many places where it would be inadvisable to use fire or steam for reheating, on account of heat or annoyance or expense, and it is in such situations that what I term a water reheater will supply enough heat units to render the pumping economical. A general illustration of this is given in Fig. 16, which shows how the suction water may, in passing around corrugated copper tubes, render valuable service in heating the air.

In actual practice the difference in the revolutions of the compressor, to do the same work, speaks immediately for the economy of the apparatus. In pumping muddy water through the reheater the deposit of mud on the tubes could be readily noticed by the increased air consumption. It is very evident that the more air cylinders on a pump the less drop in pressure will be made from one cylinder to another, and consequently less dropping of temperature. It is for this reason that, in a multi-cylinder pump, water at ordinary temperatures, acting through a number of cylinders, will yield up as many and perhaps more heat units for useful work

than a high temperature reheating before the first cylinder. It gives more time for convection, and with air, which is a poor conductor, time is required.

Referring to our last example, using three cylinders, it is evident that if the water was at 60° F. and if the air was delivered to each cylinder at 60° F., the only difference in results would be the increased volume due to the higher temperatures. This we counted as $\frac{1}{5}$. Deducting, therefore, 20 per cent. from 13,651 foot-pounds, we have 10,921 foot-pounds, which would be accomplished

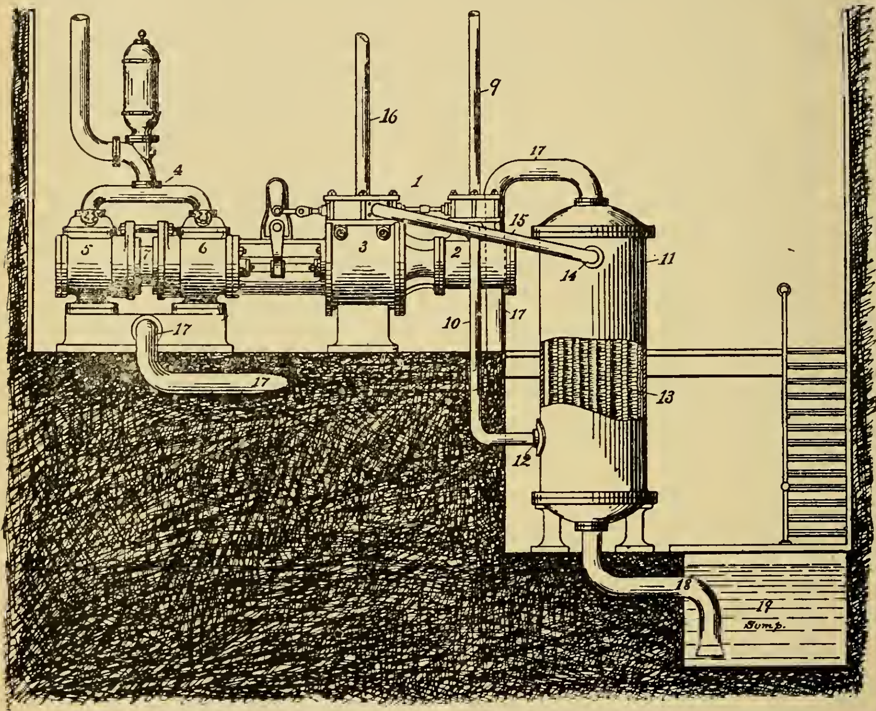


Fig. 16. Rix Compressed Air Heater, Using Water Being Pumped.

on the water-heating plan, which is more than was accomplished by heating the initial cylinder of a compound pump to 165°. Please note that this heating costs nothing and that the extra cost of the pump should not be considered. If, by water reheating, a triple cylinder pump will do 300 foot-gallons per minute, the cost for pumping water would be one-half what it would in an ordinary direct-acting pump, which power saving would of itself soon pay the cost difference.

COMBINATION OF DISPLACEMENT AND AIR-LIFT.

It seems proper, under the head of air-lift pump, to speak of the Wheeler pneumatic pump, which is a combination of displacement and air-lift, and can be used in places where there is no proper submersion for the air-lift. In fact, the system might be

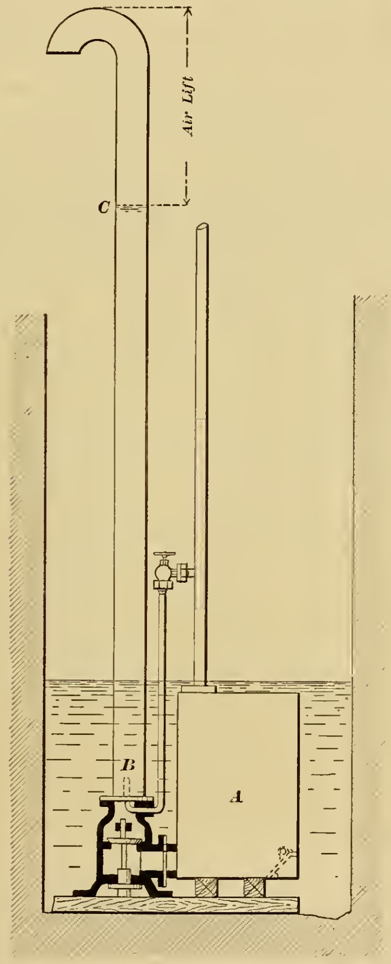


FIG. 17. A IS DISPLACEMENT CHAMBER RAISING WATER TO C, WHEN AIR FROM PIPES AT B COMPLETES THE LIFT.

called an air-lift system with artificial submersion, shown generally in Fig. 17.

The pump has two displacement chambers and an automatic valve attached, as in the Merrill pump, and the displacement action takes place similarly, one chamber filling while the other empties.

The exhaust being into the atmosphere, the expansive work of the air is lost. The Merrill pump discharges from the chambers directly to the final point of delivery, while the Wheeler pump keeps the discharge pipe filled with water at a certain height, and an air jet at its lower extremity air lifts this water to the final delivery. H. C. Behr, Esq., tested this pump during last year, and his conclusions in his report are as follows: That the efficiency of the machine as tested is such as to compare not unfavorably with the ordinary steam or air-driven direct-acting pumps of moderate size as underground in mines; that the operating expense could generally be expected considerably lower than for such pumps, on account of slight cost for repairs and replacement of worn parts; that it should require less skill and experience to operate and maintain this pump than a direct-acting pump. The efficiencies found might be somewhat increased in cases where a very efficient compressing plant is available. The efficiency will not compare favorably with high-class, air-driven compound pumps reheated. The objection to the pump is that it is not capable of raising the water by suction and is thus incapable of charging itself. It must be submerged, or the supply must be higher than the water chambers.

This method of pumping permits the displacement to take place with low pressures and thus adds to the efficiency.

Table IV accompanies Mr. Behr's report.

Test No. 21 shows the highest efficiency,—viz, 33 per cent. The air pressure was 33.75 pounds, work done 4 horse power, water lifted 1271 pounds, quantity of air 7.78 pounds per minute. Comparing this with the results obtained in the discussion of air-lift and simple displacement pumps, we have: Air pressure, 33.75 pounds; 10 per cent. for dynamic head, equals 30 pounds for active pressure. The equivalent head is 70 feet, consequently the water will stand 70 feet in the discharge pipe and the air-lift will be 35 feet, giving a submersion of 2 to 1, and air-lift pressure of 33.75 pounds.

Referring to the tables of air-lift experiments, we find that 2 cubic feet of air to 1 of water will do the work. Practically 20 cubic feet were lifted, making 40 cubic feet of air required at 33.75 pounds pressure, or 4.8 horse power. The displacement of 20 cubic feet of water at 30 pounds required 22 cubic feet of air at 33.75 pounds pressure. Allowing 10 per cent. clearance, which was 72 cubic feet of free air, this, at 12 horse power per 100, equals 8.64 horse power. $8.64 + 4.8 = 13.44$ horse power, almost identical with results shown in the table.

There can be no question that the economy of this system

could be greatly enhanced by using the expansive force of the air that is lost in exhausting from the displacement chambers, and one of the easiest means of doing this is on the principle which I suggested for the multi-stage displacement pump, as illustrated in Fig. 6.

TABLE IV.

RESULTS OF TEST OF WHEELER PNEUMATIC PUMP.

By H. C. Behr.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
					Water H. P.				Operating H. P.
Test Number.	Average Air Pressure above Atmosphere.	Weight of Air Used. Lbs. per Minute.	Weight of Water Pumped. Lbs. per Minute.	Number of Pump Strokes Approximate per Minute.	Work Realized or Water Lifted to Height of 105 Feet.	Efficiency Based on Comparison of Work Returned with Least Work Theoretically Needed for Compression.	Efficiency of Compression in Ordinary Practice.	Total Efficiency Product of Columns VII and VIII Multiplied by $\frac{85}{100}$ for Efficiency of Compressing Mechanism.	Work Spent. Indicated Work of Stream or Power Required at Motor Shaft.
	Lbs. per Sq. In.	Lbs.	Lbs.	Per Minute	H. P.	Per Cent.	Per Cent.	Per Cent.	H. P.
5	41	12.27	1,971	18	6.271	42.48	69.4	25.02	25.06
14	39	12.05	1,948	18.5	6.198	41.75	70.6	25.05	24.74
13	39	9.137	1,481	15.5	4.712	44	70.6	26.4	17.84
2	34.5	13.106	1,888	17	6.007	41.91	73.3	26.08	23.03
12	34.5	9.079	1,423	15	4.528	45.52	73.3	28.36	15.96
21	33.75	7.78	1,271	12.75	4.033	48.09	73.8	30.17	13.36
15	33 5	11.02	1,716	16.25	5.46	46.04	73.9	29.9	18.26
1	33	13.687	1,935	18	6.158	42.08	74.2	26.53	23.21
6	30.375	5.77	785	8.2	2.497	42.8	75.8	27.4	9.11
3	29.5	13.06	1,668		5.309	40.56	76.3	26.3	20.18
22	29.25	9.81	1,426	14.5	4.586	44.86	76.5	29.24	15
20	29.125	7.65	1,102	11	3.506	46.12	76.7	29.9	11.72
4	27.25	13.8	1,633	15.5	5.196	39.33	78	26.07	19.93
17	24.125	10.08	1,160	13 ?	3.69	39.84	79.5	29.9	13.71
9	24.125	5.34	730	7.75	2.323	50.15	79.5	33.9	6.85
10	23.75	10.12	1,133	11	3.605	40.43	79.8	27.4	13.15
18	19.625	7.39	608	6	1.935	33.54	82.2	23.4	8.22
11	19.5	9.397	834	8.25	2.654	36.35	82.3	25.4	10.05
19	19.375	7.6	626	8.5	1.992	33.89	82.4	23.7	8.4
7	19	9.78	856	7.8	2.724	36.35	82.6	25.5	10.63
8	14.5	7.14	350	4	1.114	24.14	85	17.44	6.39

Column pipe, 4 inches diameter.
Lift, 105 feet.

NOTE.—Test No. 16 was thrown out on account of uncertainty of speed counter observation.

CUMMINGS OR TWO-PIPE SYSTEM.

This is a simple system, compressing the air to a high pressure, say 200 pounds per square inch, and exhausting it back from the motor at 100 pounds per square inch, the idea being that full pressure motions are more economical the nearer we approach high pressures. For instance, from 0 to 100 pounds we observe quite

an extended compression curve, while from 800 to 900 pounds there would practically be no curve, but simply full pressure work, the part one wishes to utilize in direct-acting pumps.

In card No. 1, Fig. 18, the compression area is A, B, C, F, only, the area A, F, C, H, being always back pressure. The area of the compression is therefore 8 square inches, the work done is calculated at 70 per cent. as with the other examples, and this area will be $3.04 + \frac{3.04}{8'} = 38$ per cent., and if reheating be used to 300° and the exhaust be cooled off before returning to compressor, the efficiency will be 50 per cent., almost double the efficiency of the ordinary direct-acting air pump. If now we look at diagram No. 2, where we compress from 90 to 180 and exhaust at 90, we have an efficiency of 50 per cent. cold, which, by reheating to 300°, would be increased by $\frac{7}{5}$ or to 70 per cent.

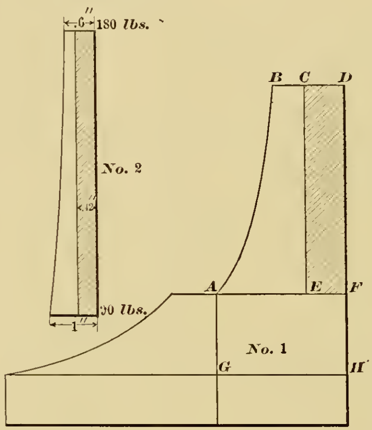


FIG. 18. DIAGRAM ILLUSTRATING THE CUMMINGS' SYSTEM.

These percentages are probably marred by frictions and leakages which I have no means of ascertaining, but I should judge that these could be kept within 10 or 15 per cent., making the simple pump show an efficiency of probably from 50 to 60 per cent. with compound compression.

These pumps can also be compounded with considerable gain, but such treatment would easily form the subject for another paper. I cannot understand why this system has not been pushed for compressed air station pumping. I believe it will be very satisfactory and economical, and some day will be extensively used. It has one advantage over the Harris system, inasmuch as the back pressure is constant, and ordinary pumps may be operated with it. The

principal objection is the high pressure and consequent leakage, and the double set of pipes and joints. This system should be regarded with high favor.

AIR-LIFT PUMPING.

While the air-lift system of pumping has recently been brought to the attention of the public, it is not a new thing, there being records of its use more than 100 years ago.

The honor of putting the air-lift system in practical shape is due to Dr. Julius Pohle, who came to San Francisco from Arizona, where he had been experimenting with several plants, one with a lift of 300 feet. Dr. Pohle established himself at the office of Rix & Firth, who interested themselves to the extent of expending considerable money in experiments to determine the efficiency of the system. A 10-inch well was sunk 60 feet deep on a piece of property belonging to the Mechanics' Institute, San Francisco. The bottom was cemented, a gallows frame 75 feet high was erected over it, and a tank and weir constructed over the well to measure the water flow. Air and discharge pipes were arranged, so that many different ratios of lift and submersion could be tried. The compressor had a compound air cylinder, actuated by a Corliss engine of 50 horse power.

The well-known civil engineer, Mr. B. M. Randall, conducted the experiments, and they were made on August 27, 1899. The results showed efficiencies as high as 52 per cent.

The records of this test are given in Table V. They are of interest as forming the first record of results in the history of air-lift pumping.

The method of operation of the air-lift is too well known to require description here.

Messrs. Brown and Behr tested the experimental plant referred to, and, in a paper read before this Society in 1890, stated that the greatest efficiencies were obtained when the submersion of the pipe was twice the lift, and with this submersion an efficiency of 50 per cent. was obtained.

Quite extensive experiments have been made in Germany to determine the efficiency of the air-lift, and their results fall somewhat short of the percentages obtained in this country. The efficiency was the ratio of work in discharged water to the indicated compressor work and ranges from 45 to 30 per cent., with smooth pipes,—a lift of 50 feet, and a submersion of from 4 to 3, to 3 to 2.

The amount of water discharged increases with the quantity as well as with the pressure of the air, but the efficiency falls away

TABLE V.—EXPERIMENTS WITH POHLE AIR-LIFT, 1889.

1. Number of Tests.	2. Number of Compressor Strokes per Minute.	3. Pressure per Sq. In. in Receiver.	4. Weir Head. Inches.	5. Length of Water Pipe below Surface of Water. Ft.	6. Length of Water Pipe below Surface of Water. Ft.	7. Temperature in Receiver. Fah.	8. Temperature of Air in Room. Fah.	9. Temperature of Water at Weir. Fah.	10. Quantity of Water Pumped per Second. Cu. Ft.	11. Weight of Water Pumped per Second. Lbs.	12. Quantity of Water Pumped in 24 Hours. Gallons.	13. Work per Second of Pumping the Water. Foot-Lbs.	14. Air at 75° Fah. Compressed per Second. Cu. Ft.	15. Work of Compressing Air per Second. Foot-Lbs.	16. Resistance in Water Pipe. Foot-Lbs.	17. Resistance of 3 Bends in Air Pipe. Foot-Lbs.	18. Resistance of 3 Bends in Air Pipe. Foot-Lbs.	19. Resistance of ⅝″ Nozzle in Air Pipe Foot-Lbs.	20. Resistance of Circular Bend in Water Pipe. Foot-Lbs.	21. Resistance due Velocity of Discharge. Foot-Lbs.	22. Sums of Work of Pumping and Resistances as Determined. Foot-Lbs.	23. Efficiency of Pump. Per Cent.
1	59	31.15	4.1	75.55	55.78	77°	72.6°	68°	0.0799	11.25	116.576	850	1.086	2,616	832	652	80	88	8	63	2,583	33
2	45	27.86	3.8	75.55	55.78	78°	70.7°	68°	0.1488	9.3	96.4	703	.878	1,864	481	325	39	38	5	37	1,628	38
3	30	25.64	3	75.55	55.78	79°	74°	68°	0.0824	5.15	53.495	389	.552	1,180	159	155	19	14	1	13	1,050	33
4	59	30.69	5.2	35.53	55.5	74°	72°	71.6°	0.3259	20.37	281.578	724	1.076	2,569	1,050	458	80	88	15	58	2,473	28
5	46	26.4	5.1	35.53	55.5	78°	71.6°	68°	0.3105	19.41	201.204	690	.846	1,842	570	400	48	48	10	68	1,834	37
6	30	24.78	4.6	35.53	55.5	78°	73.2°	68°	0.2398	14.99	155.39	533	.552	1,155	325	155	19	14	4	33	1,083	46
7	22	24.16	4.25	35.53	55.5	78°	72.5°	68°	0.1965	12.3	99.662	437	.405	834	160	97	11	11	2	18	736	52.4
8	60	24.1	3.85	54.7	36.33	78°	73°	70°	0.1538	9.61	60.329	526	1.104	2,269	631	580	89	86	9	12	1,933	23
9	35	17.58	3.15	54.7	36.33	78°	73°	70°	0.0931	5.82	37.325	318	.644	1,072	118	190	29	28	2	14	699	30
10	22	16.17	2.6	54.45	36.58	74°	74°	69°	0.0576	3.6	62.726	196	.405	636	36	77	11	11	5	4	340	31
11	60	20.58	3.2	63.16	27.87	80°	77°	69°	0.0968	6.05	21.902	382	1.104	2,046	137	281	89	86	2	44	1,021	19
12	60	18.75	2.1	70.66	20.37	76°	72°	69°	0.0338	2.11	42.962	149	1.104	1,851	401	514	89	86	6	15	1,260	8
13	38	15.29	2.75	63.16	27.87	80°	74.5°	70°	0.0663	3.96	11.988	250	.669	1,051	106	194	35	34	2	12	633	24
14	19	12.28	1.65	63.16	27.67	79°	75°	71°	0.0185	1.16	72.965	70	.35	450	8	54	8	8	0	1	147	16
15	34	12.35	3.4	31.5	20	79°	71.5°	69°	0.1126	7.04	147.696	222	.616	795	80	137	28	28	2	15	508	28
16	60	20.46	4.5	25.25	26.25	69°	66°	67°	0.227	14.19	131.285	358	1.104	2,039	618	495	89	86	15	115	1,775	18
17	41	15.8	4.3	25.25	26.25	70°	66°	67°	0.2026	12.66	98.247	320	.754	1,175	280	230	41	39	7	52	969	27
18	22	12.52	3.74	25.25	26.25	70°	66.5°	67°	0.1439	8.99	93.286	226	.405	528	66	65	11	11	1	12	392	43
19	60	22.13	5	20.25	31.25	72°	67.5°	69°	0.2954	18.46	147.296	374	1.104	2,147	832	537	89	86	20	152	2,090	17
20	27	15.22	4.5	20.25	31.25	72°	68°	69°	0.227	14.19	139.061	287	.497	748	167	110	18	17	4	32	635	37
21	22	14.52	4.4	20.25	31.25	72°	67°	69°	0.2146	13.42	232.826	272	.405	589	118	71	11	11	3	22	507	46
22	60	23.12	5.4	15.25	36.25	74°	67°	68.5°	0.3593	22.45	211.183	342	1.104	2,209	926	582	89	86	25	141	2,091	16
23	30	17.46	5.2	15.25	36.25	73°	69°	69°	0.3259	20.37	164.01	311	.552	911	352	111	19	14	10	66	883	34
24	19	16.2	4.72	15.25	36.25	73°	69°	69°	0.2531	15.82	44.906	241	.35	550	133	59	8	8	3	25	477	44
25	60	17.05	2.8	36	15.5	74°	69.5°	69.5°	0.0693	4.33	27.475	156	1.104	1,800	182	398	89	86	5	34	950	9
26	34	10.17	2.3	36	15.5	74°	70°	70°	0.0424	2.65	6.026	93	.616	880	37	123	28	26	1	7	315	11
27	18	7.46	1.25	36	15.5	73°	70°	70°	0.0093	0.58	9.461	21	.331	288	2	36	7	7	0	14	73	7
28	60	15.87	1.5	41	10.5	76°	72°	70°	0.0146	0.92	116.575	38	1.104	1,712	38	360	89	86	1	7	619	2
30	60	31.66	4.1	75.78	55	82°	70°	10.8°	0.1799	11.24	109.577	852	1.104	2,685	836	674	89	86	9	65	2,611	32
31	60	31.66	2.9	75.78	55	84°	71°	110°	0.1691	10.57	44.054	801	1.104	2,685	792	674	89	86	9	70	2,521	30
32	28	25.28	4.1	75.78	55	84°	71°	114°	0.0757	4.73	49.554	359	.515	1,091	92	161	19	18	1	7	719	33
33	60	31.66	4.1	75.8	55	81°	70°	116°	0.1799	11.24	116.575	852	1.104	2,685	836	674	89	86	9	65	2,611	32
34	60	31.28	4.1	75.8	55	80°	70°	82°	0.1796	11.24	116.575	851	1.104	2,666	836	674	89	86	9	65	2,610	32

very rapidly when the output is forced. A submersion of 50 feet and a height of discharge of 25 feet, with increasing quantities of air, gave quantities of water from 4 to 15 cubic feet per minute. The quantity of air varied from 76 to 105 cubic feet per minute, and the ratio of free air to the water lifted varied from 1.96 to 7.6, the efficiency being in a like proportion.

In another set of experiments, with lifts from 43 to 230 feet, submersion from 92 to 400 feet, from 2.9 to 5 cubic feet of air was required per cubic foot of water pumped, and the pressures were from 30 to 160 pounds.

The quantity that can be handled is practically unlimited.

It is safe to calculate on velocities in the pipe from 4 to 8 feet per second, and it will take from 2 to 3 cubic feet of atmospheric air per cubic foot of water pumped for heights from 15 to 50 feet, and from 50 to 100 feet I should figure on from 3 to 4 cubic feet of air per cubic foot of water.

I believe that for very low heads the air consumption may be still further decreased, and that 1.5 cubic feet of air will lift a cubic foot of water 20 feet high.

Engineering News, Vol. XXVII, page 140, gives some interesting data on air-lift pumping at Rockford, Ill.

The pumping was done from four wells, 84 feet, 84 feet, 82.5 feet and 59 feet from surface to water while being pumped and 7½ additional into a tank with an air pressure of 76 pounds per square inch.

The wells were close together. A 2½-inch pipe led from the reservoir to each well and a 1½-inch pipe was continued in the well casing with 225 feet submersion.

The discharge was 2,000,000 gallons per 24 hours. From the steam indicator diagrams it appears that 124 horse power was used The average yield was 1401 gallons per minute, and the net work done was 24 horse power on an efficiency of 20 per cent.

A 14 x 22 duplex compressor made 96 revolutions to do the work. This would give about 600 cubic feet of free air. About 200 cubic feet of water were pumped, or 3 cubic feet to 1, a result which represents the average. The efficiency is low because the compressor took too much power. In a compound compressor 600 cubic feet of air should be compressed to 76 pounds for an expenditure of not more than 100 horse power. This would make the efficiency about 25 per cent.

The air pressure was excessive, and this was due no doubt to the small well casing, because with proper well pipes 50 pounds air pressure would have been ample.

Fig. 19.

I have not yet succeeded in making any general rules for sizes and capacities for air-lift pumping. There is generally a surprise waiting for us, no matter what we do. There should be some particular relation of all the quantities concerned that will give the best results, and yet, for a considerable variation either way, in submersion and air pressure, the quantity of water will remain the same.

The relation between the diameter of the discharge pipe and the velocity of water seems to be a delicate one. I should think that 5 feet per second would establish a good proportion. The air pipe must be large enough to minimize the friction loss.

The initial air pressure will, of course, be that due to the submersion, and will decrease after the discharge begins, until with a 3 to 2 submersion the pressure will correspond to a head of about one-half the submersion plus the lift.

In flowing artesian wells the best results seem to be obtained by giving deep submersion, small air quantity and high pressure.

Sand may be cleared from a well by filling the air reservoir with air at a high pressure, then suddenly releasing it, the air pipe having first been given quite a submersion. The sand comes out in masses and can be seen distinctly. In Fig. 19 one-half the column of water measured over 100 feet above the mouth of the well. It will be noted that about 20 feet above the mouth of the well the water seems to radiate in all directions from one center. It would seem that a bubble of compressed air had been carried up there and then suddenly expanded. The efficiency of the air lift naturally increases directly in proportion to the temperature of the water.

The air-lift has a special field of usefulness and will scarcely be given over to much competition with other pumps.

When a large quantity of water must be brought out of a small casing, no other method would be so satisfactory. If an artesian well fails to deliver to the proper point by a few feet, no other system could make it deliver its water so efficiently. For example, at Alvarado one of the large artesian wells refused by about two feet to flow into the general cachement basin. Nothing could be done but pump it, and this would require a centrifugal pump capable of handling 1000 gallons a minute to restore the required quantity. A one-inch compressed air pipe inserted 155 feet into the well, and consuming 6 horse power of compressed air, stimulated the well to complete action.

The plain open-air pipe seems to be the best means of ending the air pipe in the well and whether it point up or down is not

TABLE VI.

Head.	Quantity of Free Air.	Quantity of Water. Gallons.	Air P. in Receiving.	H. P. of Air.	H. P. of Work Performed.	Efficiency.	Submersion.	Ratio Air to Water.
39	170	750	37	20	8	40	60	1.7-1
30	150	400	20	11	3	27	45	-1
35	170	600	39	21	6	30	70	2.2-1
32	100	500	39	12	4	33	87	1.5-1
22	50	187	10	2	9	45	30	2

TABLE VII.

Experiment in Artesian Air-Lift Pumping.

Depth of Well.	Size of Casing.	Natural Flow.	Height to Raise Casing to Stop Flow.	Submersion.	Quantity of Free Air.	Air Pressure.	H. P. to Beneath Air.	Pumping Head.	Quantity of Water Pumped. Gallons.	H. P. in Water.	Efficiency.	Ratio Air to Water.
950	5 & 8	200	6′	180	135	73	24	33	1300	11	46	0.8-1
950	5 & 8	200	6′	110	135	41	165	30	800	6	36	1.3-1
950	5 & 8	200	6′	146	135	56	20	32	900	7	35	1.2-1
700	7	20	1	100	120	38	16	30	800	6	38	1.2.1

TABLE VIII.

For Air-Lift Pumping.

Diam. Air Cyl.	Stroke.	Cu. Ft. Free Air at 100 Revs.	Cu. Ft. Free Air at 125 Revs.	Suitable Pumping Heads.	Quantity Pumped at 100 Revs. in Gals.	Quantity Pumped at 126 Revs.	H. P. Required 100 Revs.	H. P. Required 125 Revs.	Ratio of Submersion to Lift.
60 to 100 Lbs. Pressure.									
10	12	92	108	80-120	200-175	232-205	12-17	15-20	3-2
12	15	165	195	80-120	350-310	420-370	22-32	26-36	3-2
14	16	245	288	80-120	525-465	620-550	35-45	38-55	3-2
30 to 60 Lbs. Pressure.									
12	12	132	152	40-80	330-285	380-325	12-18	14-20	3-2
14	15	229	270	40-80	570-500	675-580	22-30	25-35	3-2
16	16	312	368	40-80	780-670	920-800	30-40	35-50	3-2
10 to 30 Lbs. Pressure.									
14	12	183	216	10-40	640-450	850-540	8-18	10-22	3-2
16	15	293	345	10-40	1,000-730	1,200-860	13-30	15-35	3-2
18	16	408	480	10-40	1,400-1,000	1,700-1,200	18-40	21-50	3-2

material. Dividing the air into minute bubbles by fine perforations seems not to do as well as the open pipe.

I have compounded the air-lift into several lifts, one discharging into the other, with fair results, but it would be better to discharge each section into an open tank and let the water dispose of its air bubbles.

The greatest general efficiency of the system will become apparent under conditions where the number of wells that can be operated by an engine plant do not yield enough water without lowering the surface of the water too far. Let us say that normally the water stands at 20 feet from the ground, and, in order to get the quantity from six wells, they are lowered to 80 feet by sinking perhaps six more wells some greater distance away, and all twelve are worked with the air-lift. The pumping may be done at a head

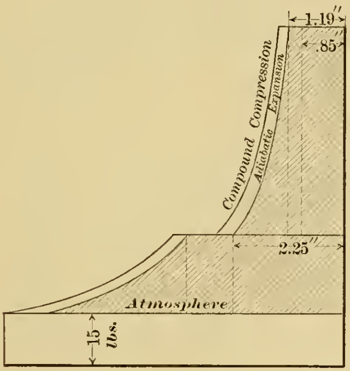


FIG. 20. DIAGRAM OF COMPOUND DOUBLE REHEATED AIR MOTOR FOR PUMPING.

of only 40 feet. This would be possible, of course, with pumps, but not practical.

In general, and within pumping limits of 120 feet, I shall conclude that from 50 to 60 per cent. efficiency is possible, but 30 to 40 per cent. will probably more nearly represent the average plant.

Tables VI and VII give the results of experiments made last year, and Table VIII gives some general requirements for air-lift pumping.

MOTOR-OPERATED PUMPS.

This class consists of pumps belted, geared or direct connected to engines of all kinds. There is no doubt that, with Corliss engines, coupled directly to pumps, the mechanical efficiency is as high as 85 per cent. Let us take an example on this basis, using compound compression, with engines cross-compound and double reheated to 300°, or $\frac{7}{5}$ increase of volume.

The comparison of curve areas, Fig. 20, shows that an efficiency of 88 per cent. should be obtained. This, it must be understood, is for a station pump, where all proportions are specially designed for the one object in view. In my calculations no account is taken of reheating. The expense is small, and I should think might be taken as 5 per cent. of the economy, consequently this sum should be deducted from all of my reheating calculations. It costs practically the same to heat to 300° or 400° as to 200°, provided the reheater is close to the motor, as it should be. The amount of air required by engines per horse power will vary from 25 to 5 cubic feet per minute of free air, according to the amount of reheating and the amount of expansion used.

TABLE IX.

RECAPITULATION.

90 Lbs. Air Pressure on Main.

Kind of Pump.	Foot-Gallons.	Efficiency, Simple Compound.	Efficiency, Compound.
Direct-Acting Simple	135	19	20
“ “ “ 300 reheated	180	24	28
“ “ Compound Water reheated	232	32	375
“ “ “ 1 cylinder heated 300	280	40	46
“ “ “ 2 “ “ 300	326	46	53
“ “ Triple 3 “ “ 300	383	54	62
“ “ “ 3 “ “ 400	444	63	72
Plain Displacement.	175	22	25
Wheeler “	34% for 34 lbs. pressure		
Multiple “	320	40	46
Harris “		60 to 70%	
Merrill “	175	22	25
Cumming System		35 to 70%	
Compound Motor Pumps		50 to 80%	
Direct-Acting Triple Water heated	300	42	48
Pohlé Air-Lift	30 to 60% heads less than 200 ft.		

The loss in the compressed air problem is one of heat. The air is all there; none of it gets away. If this heat be restored and a sufficient quantity added to overcome leakage and clearance, we shall get back our original expenditure, of course, less the mechanical losses in the motor. Inasmuch as, in compound compression to 90 pounds, the temperature need not at any time exceed 225°, what is there to hinder our returning this and much more besides, when we have 500° at our service? I have used 430° in a Corliss motor, with excellent results, and I believe another 100° could have been added. The whole question is one of temperature, and the successful solution lies in special and intelligent adaptation of the forces at our service.

Too many have condemned compressed air without proper hearing, and I hope these remarks may stimulate some one to give special attention to the pump problem and give us some pumps worthy of the atmosphere which they now so generously use.

In conclusion it may be stated that I do not wish to be understood as giving absolute values to the quantities mentioned in this paper. Others may find in their experience that I have allowed too little or too much for mechanical efficiencies, or that I have assumed too high a standard pressure. This does not interfere with the comparative values of the various systems, which is the real point toward which I have desired to direct your attention.

For Figs. 2, 3 and 4, and accompanying notes, see pages 214, 215 and 216.

THE COMPOUND DIRECT AIR-PRESSURE PUMP WITH ADJUSTING RECEIVER.

Computations for Proportioning the Parts and a Graphical Presentation of one Cycle of Operation.

The Problem.—Proportion a system to lift 66 cu. ft. (500 gals.) per minute 200 feet in the lower stage, and 650 gals. (87 cu. ft.) per minute 175 feet in the upper stage, assuming lengths of air pipes to be 500 feet to lower and 300 feet to upper tanks.

Note.—In the following computations it is assumed that no change in temperature occurs and friction of air and of water in pipes is neglected.

Solution—Horse Power.—From figures given above the average net horse power = 55. But the max. rate of work per stroke is 10,900 ft.-lbs. (See ordinate at K, Fig. 3.) Assuming the compressor to work at 90 revolutions (or 3 strokes per sec.) this will give about 60 H. P.

Air Pipes.—If the volume of compressor stroke is previously known the max. velocity in air pipe of known area can be found by observing that immediately after switching the whole volume of compressor stroke goes through the air pipes.

Otherwise an approximate rate is: The max. air volume = 6 times the average water volume discharge. In this case the rule gives 5.5 cu. ft. per sec. of air at 102″. Hence select air pipes 4″ diam.

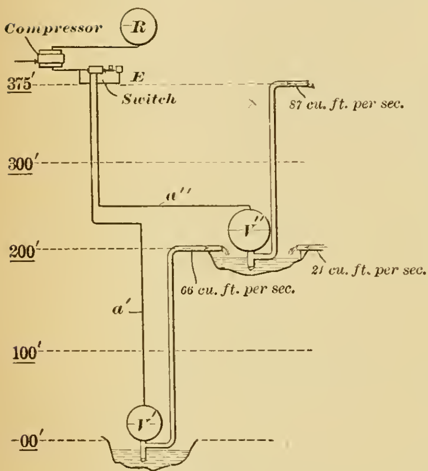


Fig. 2.

Tanks.—They should not be less than 10 times the vol. of air pipe. Hence assume V′ = 450 cu. ft. Then if no receiver were attached V″ would be computed by Eq. I, which would give V″ = 525; but by conditions of the problem, V″ must be = 1.3 V′ = 585. This requirement can be satisfied by attaching a receiver whose volume will be computed by Eq. II, whence R = 497.

In practice make V″ and R larger to permit adjusting, which can be done by pumping water in or out of R.

Notes on the Operation.

When air is switched out of V″ it expands into pipe a′, and thereby drops from 91″ to 88″ (G″ to A), then compressor forces air into V′, but no water will be delivered until pressure in V′ reaches 102. In the meantime pressure in V″ will be worked down to 76.5, which will require 47 strokes. (See A to B′ and A to B″.)

When air is switched out at V′ we will have V′ + R + a′ at 102″, while only 91″ is necessary to force water out of V″. Hence water will discharge without further action of compressor until all pressures drop to 91″. The volume of water thus displaced will be 96 cu. ft. This cannot be properly shown on the diagram. It occurs between D‴ and E‴, but as these points are coincident in time the effect will be to run the delivery curve up as shown in the dotted line near E‴.

Formulas III and IV do not apply after Pn falls below atmospheric pressure, for V′ (or V″) is then a variable. Hence the broken lines between C and D and F and G are not computed.

The two lines in each pair of heavy verticals S″ S″ and S′ S′ are coincident in time. The intervening space is for convenience in showing connections between curves.

SYMBOLS AND NUMERICAL VALUES.

P′ = Absolute max. pressure in lower tank.
P″ = " " " " upper "
p′ and p″ = Absolute min. pressure in either tank.
a′ = Volume of air pipe to lower tank.
a″ = " " " " upper "
V′ = " " lower tank.
V″ = " " upper "
R = " " receiver.
v = " " compressor stroke.
n = Number of compressor strokes.
Pn = Variable pressure in tanks.
W = " work per stroke.
Vx = " water volume delivered per stroke.

FORMULAS.

$$V'' = \frac{P' (V' + a') + p'' a'' - p' a'}{P''} - a'' \ldots\ldots\ldots \text{I}$$

$$R = \frac{P'' (V'' + a'') - P' (V' + a') + p' a' - p'' a''}{P' - P''} \text{II}$$

$$Pn = Po \left(\frac{V + a}{V + a + v} \right)^{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{III}$$

Po = initial pressure, Pn = that after *n* strokes.

$$n = \frac{\log. Po - \log. Pn}{\log. (V + a + v) - \log. (V + a)} \text{IV}$$

$$Wx = Px\, V \log. \frac{Po}{Px} \ldots\ldots\ldots\ldots\ldots \text{V}$$

$$Vx = \frac{Px}{P'}\, v \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{VI}$$

The proper value for v is found by trial in Eq. IV.

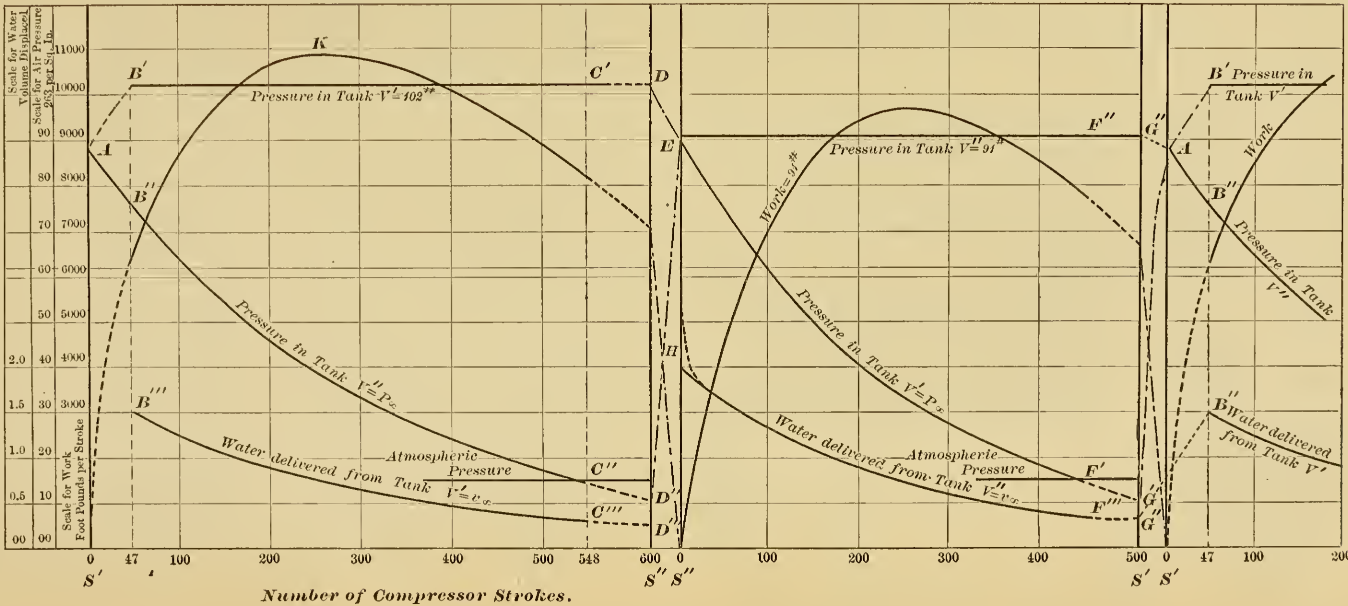


FIG. 3.

SHEET No. 12.

The Compound Direct Air-Pressure Pump.

Diagrammatic Presentation No. 1. Pump applied to a single source with single lift.

Diagrammatic Presentation No. 2. Pump applied to wells in groups.

Diagrammatic Presentation No. 3. Pump applied in a "two-stage" lift.

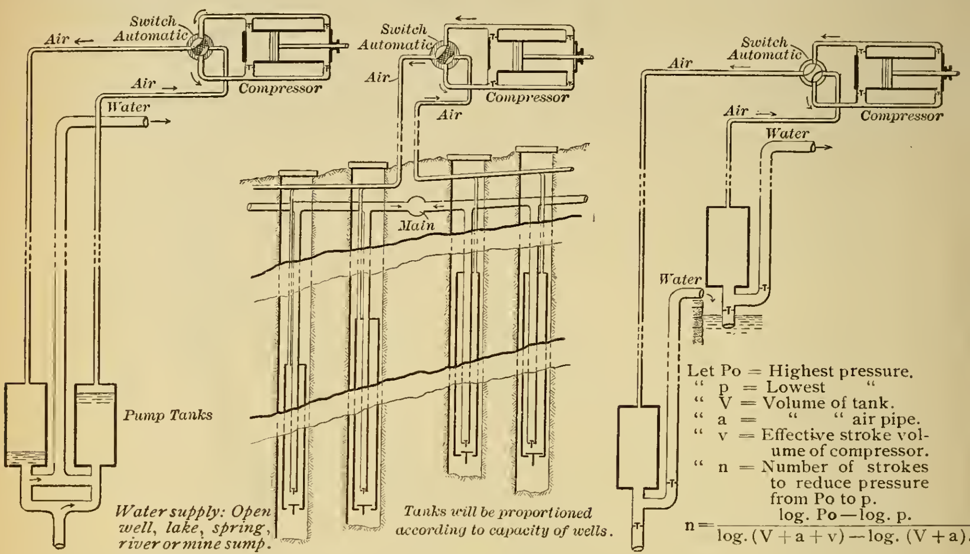


FIG. 4.

Notes on Operation.

One tank (or group of tanks) is emptied by air pressure while the other is drawn full by suction, the air charge being so adjusted that one tank is drawn full of water just when the other is emptied.

The switch can be automatically operated in either of three ways:

1. By means of the suction in the intake to compressor, which depends on the height to which water must be drawn in filling the tanks.

2. By a mechanism that will throw the switch at a given number of compressor strokes, the number required being that which will empty one tank and fill the other.

3. By an electrically controlled mechanism, the circuit being controlled either by floats in the pump tanks or by a pressure gage on the intake pipe.

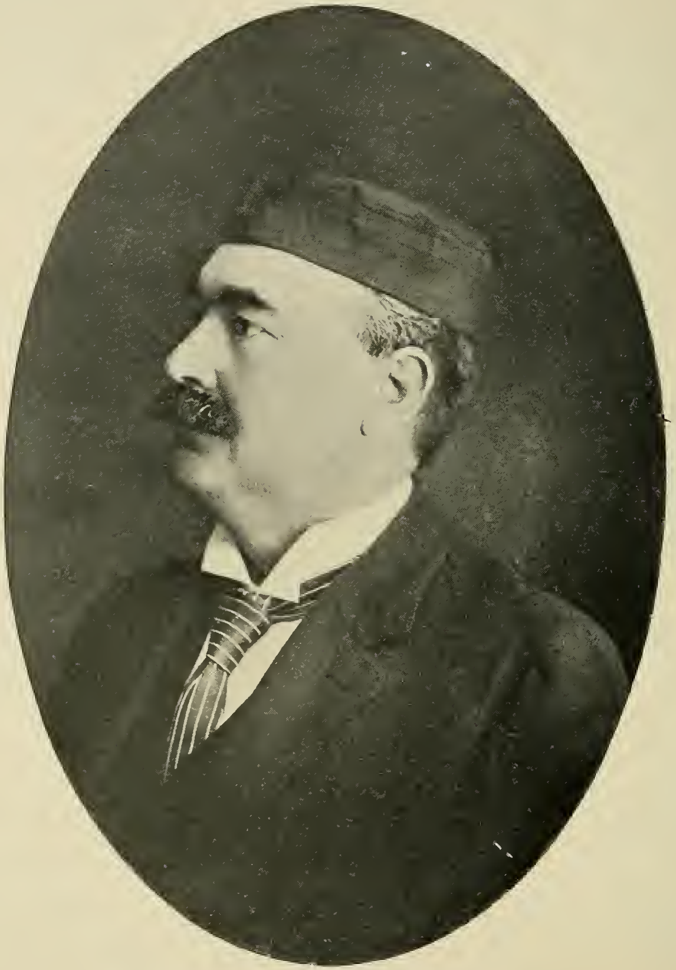
Advantages.

1. The expansive energy in the compressed air is fully utilized.

2. There are no moving or delicate parts outside the compressor room, except the check valves on water pipes.

3. One compressor can pump water from any number of sources.

4. In mine drainage the tanks may be submerged to any depth.



WILLIAM GIDDINGS CURTIS.

Member, Technical Society of the Pacific Coast.

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THE EXPERIMENTAL FILTER PLANT AT PITTSBURGH.

BY MORRIS KNOWLES, C.E., ASSISTANT ENGINEER IN CHARGE OF TESTING STATION, IMPROVEMENT AND FILTRATION OF THE WATER SUPPLY, PHILADELPHIA. FORMERLY RESIDENT ENGINEER, FILTRATION COMMISSION, PITTSBURGH.

[Presented June 20, 1900.*]

GENERAL.

THE city of Pittsburgh has a population of about 320,000, of which about 235,000 are supplied by the municipal works, which pump water from the Allegheny River. The remaining 85,000 are supplied by private companies, and almost all of the water for these is pumped from the Monongahela River. We are interested at this time in the supply from the Allegheny alone; and the water from this river, in regard to turbidity, may be said to be midway between the streams of New England and those of the Ohio and Mississippi Valleys. It is occasionally very muddy, carrying large quantities of fine silt and clay. It is also polluted by sewage from many cities, towns and mining villages, together with considerable mine drainage at times.

In June, 1896, the City Councils authorized the appointment of a Filtration Commission, to be composed of the Mayor, the Presidents of the Councils and eight representative citizens, two of whom were to be physicians. This commission, to quote the substance of the resolution, was to investigate the character of the present water supply, the effect of filtration, the advisability of establishing a filtration plant, and furnish an estimate of constructing and maintaining the same; also to investigate the feasibility and advisability of seeking other sources of supply.

*Manuscript received October 27, 1900.—Secretary, Ass'n of Eng. Socs.

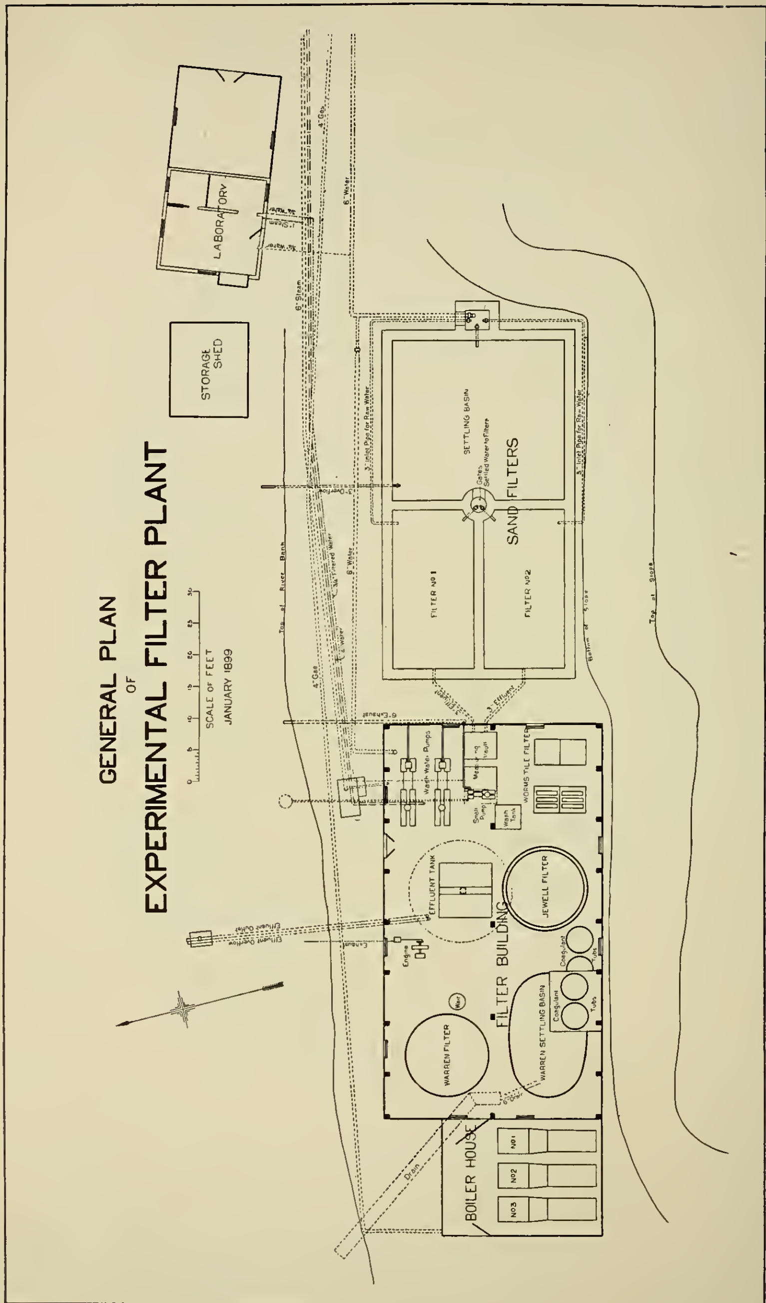

GENERAL PLAN
OF
EXPERIMENTAL FILTER PLANT
SCALE OF FEET
JANUARY 1899
STORAGE SHED
LABORATORY
SETTLING BASIN
SAND FILTERS
FILTER NO 1
FILTER NO 2
Top of River Bank
Top of Slope
Bottom of Slope
EFFLUENT TANK
JEWELL FILTER
WARREN FILTER
WARREN SETTLING BASIN
FILTER BUILDING
WORMS TILE FILTER
Wash Water Pumps
Wash Tank
Engine
Coagulant
Tubs
BOILER HOUSE
NO1
NO2
NO3
Drain

FIG. 1.

Mr. Robert Pitcairn, General Agent of the Pennsylvania Railroad, was Chairman of the Commission, and Mr. Allen Hazen, of New York city, was Consulting Engineer. Dr. Walther Riddle, of Pittsburgh, had charge of all chemical analyses, which were made in the private laboratory of Coster & Riddle. Mr. Wm. R. Copeland, formerly of the Experiment Station of the Massachusetts State Board of Health, at Lawrence, Mass., had charge of the bacteriological laboratory, located at the filter plant. He was also in direct charge of the operation of the experimental filters.

It is proposed in this paper to confine our attention to that portion of the investigations which was carried on at the experimental filter plant; to present a short description of the apparatus used, with views of some of the interesting details, and briefly to summarize some of the results obtained.*

In May, 1897, preparations were made for beginning experiments with various types of filters, and upon July 23 the sand filters were placed in operation. Upon January 14, 1898, the mechanical filters were started. The tile filters were first started November 25, 1897, and again, after two months of idleness, upon June 12, 1898. The experiments were officially closed September 1, 1898, and the report of the Commission was transmitted to Councils in January, 1899.

DESCRIPTION.

The experimental filter plant was located at the pumping station of the municipal water works, at Brilliant Station, on the Allegheny Valley Railway, about six miles from city hall. Fig. 1 shows the general arrangement.

The plant consisted of two sand filter basins, with a settling basin about equal in area to both combined; a filter building, in which were located the measuring vault of the sand filters, the mechanical and tile filters, the filtered water tank, the wash water pumps and other machinery, also the experimental boilers (see page 000). Water was supplied to the plant from a large force main in the yard and was thus of about the same character as the river water, and changed nearly as rapidly as that in the river.

SAND FILTERS.

Description. A plan and vertical section of the two sand filters are shown in Fig. 2, together with a vertical section

*A report upon the whole subject, together with a more complete description of the experimental work and a discussion of the results, will be found in "Report of Filtration Commission, Pittsburgh, 1899."

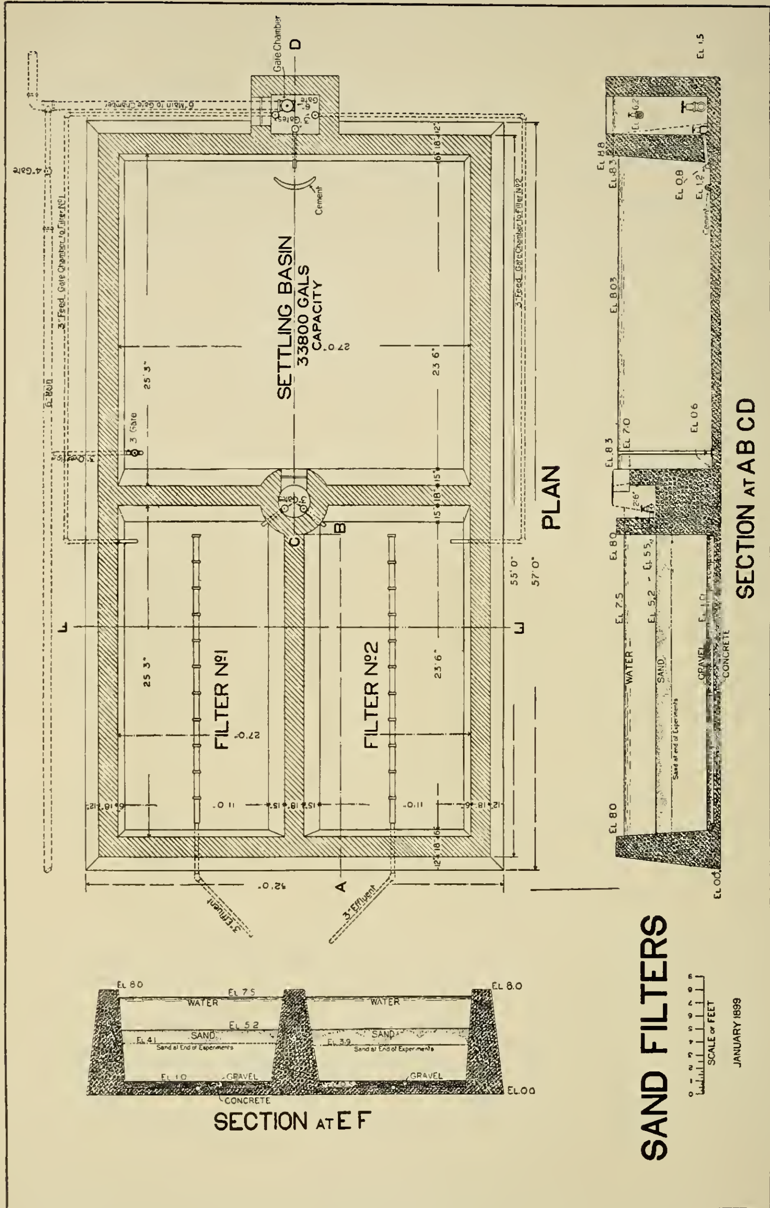


FIG. 2.

through Filter No. 2 and the settling basin. A view of them is given in Fig 3. The walls and bottom were built of concrete. The filters were not covered. The settling basin had a capacity

of about 33,800 gallons which, if complete displacement were realized, would have allowed twenty-four hours' sedimentation when one filter only was supplied with settled water. It is believed, however, that changes from inlet to outlet were accomplished in about two-thirds of this time. The average area of the sand surface was 0.0065 acre during the experiments, being about 12 square feet less at the close than at the beginning, owing to the batter of the walls.

The underdrain pipes were vitrified and 4 inches in diameter. Broken stone and gravel, to a depth of 6 inches, were placed on the concrete bottom and over the pipe. The layers of under-

FIG. 3. SAND FILTERS AND SETTLING BASIN.

draining material were as follows: Three inches of broken stone of about 3 to 2½ inches in size, which was covered with screenings, or somewhat smaller broken chips, to close the larger interstices on top; 1¾ inches of clean river gravel of about ¾ to 5-16 inch in size; 1¼ inches of clean river gravel which had been passed through a 5-16-inch screen. Allegheny River sand, which was deposited loosely in six layers for a depth of 5 feet, completed the beds. After it had settled in water for a few days the thickness diminished to 4.2 feet, which was the amount in place at the beginning of the experiments. An average of 1.2 feet was removed during the thirteen months of operation. Fig. 4 shows the method of scraping and the care taken by the attendant, by

using sandals, not to make indentations in the sand surface. The average composition of the sand used may be seen in the following table:

RESULTS OF ANALYSES OF SANDS USED IN THE SAND FILTERS.

SOURCE OF SAMPLE.	Effective Size (10% Finer than M. M.)	Uniformity Coefficient. Size (60% finer than) divided by Size (10% finer than)	PARTS BY WEIGHT. Iron and Aluminum Oxides.	Calcium Carbonate.	Silicates and Insoluble Matter.
Filter No. 1.	0.30	2.0	0.98	1.32	97.70
" " 2.	0.31	2.0	0.96	1.35	97.69

FIG. 4. SAND FILTER, METHOD OF SCRAPING.

Apparatus. The effluent pipes were brought, side by side, into a small vault in the filter building, in which were placed the necessary devices for regulating and registering the quantity of water filtered. Meters were rendered unreliable by the amount of air carried in the water. Orifice indicators were therefore relied upon, and these had the additional advantage of indicating the rate of filtration at the instant of observation. Fig. 5 shows two views of one of these indicators. Ten standard orifices were drilled in the $\frac{1}{8}$-inch brass bottoms of copper cans 12 inches in diameter and 12 inches in depth. The water entered the side of the indicator and passed through a screen to prevent cross currents. On one side of the indicator was a glass slide, upon which a scale was fastened. The scale was graduated to read, upon one edge, in "Gallons per

Orifice, Daily," and, upon the other, in "Million Gallons per Acre, per Orifice, Daily."

The attendant was instructed to keep the water, on the latter scale, at the half-million rate mark as nearly as possible, so that half the number of orifices open corresponded approximately to the rate of filtration. Orifices not in use were closed with rubber stoppers. The loss of head was read downward directly upon a movable scaleboard, the zero of which was changed frequently during the day to agree with the level of the surface of the water outside on the filter basin. Various rates of filtration were used, between two million and five million gallons per acre daily, with both settled water and that which came directly from the river without any appreciable rest.

FIG. 5. SAND FILTERS, ORIFICE INDICATORS.

The turbidity of the river and settled waters was determined by observing the distance below the surface which a platinum wire could be seen in the water. The record was expressed as the reciprocal of the depth, in inches, at which the wire just disappeared from view. The turbidity of the effluents was observed by comparison, in gallon bottles, with standards of known turbidity, which were made from a stock silver nitrate solution, precipitated in distilled water with sodium chloride. The relation between the two standards was determined approximately, and all results were expressed in terms of the method first mentioned.

Results. The average quantitative and bacterial results secured with the sand filters during the thirteen months are given in the following table, No. 1. The figures given in this and subsequent tables are, in some instances, slightly different from those found in the report of the Filtration Commission. The difference is due to rounding up and using even figures:

TABLE No. 1.

AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

Months.	Hours in Operation per Day.		Rates of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1.	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1897.														
August	23.8	22.9	2.40	2.30	0.18	0.13			2,090	1,280	46	42	97.80	97.99
September	24.0	24.0	2.98	3.00	0.05	0.04			2,480	1,230	16	16	99.35	99.35
October	23.3	23.7	2.90	2.95	0.03	0.03			72,900	39,200	32	32	99.96	99.96
November	21.5	20.1	2.64	2.42	0.26	0.18			25 200	29,900	346	632	98.63	97.49
December	22.4	23.5	2.76	2.46	0.19	0.14			14,400	14,900	163	225	98.87	98.44
1898.														
January	22.5	22.8	2.77	1.87	0.27	0.15			15,300	13,800	334	310	97.82	97.98
February	23.5	23.4	2.93	2.27	0.15	0.10	0.011	0.011	9,430	12,000	266	275	97.18	97.08
March	23.5	22.7	2.95	2.83	0.28	0.17	0.013	0.017	11,700	12,300	71	332	99.40	97.17
April	23.4	23.5	2.95	2.99	0.08	0.08	0.003	0.005	5 010	4,930	33	91	99.34	98.18
May	23.6	23 6	2.93	2.95	0.19	0.12	0.012	0.011	10,800	6,770	110	99	98.98	99.08
June	22.8	22.9	2.83	2.85	0.19	0.11	0.011	0.012	11,100	5,930	135	72	98.78	99.35
July	23.5	23.6	2.94	4.97	0.11	0.07	0.003	0.003	16,800	13,000	74	89	99 56	99.47
August	22.8	23.1	2.85	4.82	0.36	0.25	0.008	0.017	15,100	10,250	51	82	99.66	99.46
Average, 13 months	23.1	23.1	2.83	2.98	0.18	0.12	——	——	16,400	12,800	128	176	99.22	98.93

NOTES.—Filter No. 1 was operated with settled water all the time, except for occasional days

Filter No. 2 was operated with water not settled, but applied directly from the river, from July 24 to December 19, 1897, and from February 20 to June 30, 1898; and at other times with settled water.

Leaks and Cold Weather. In partial explanation of some of the relatively low bacterial efficiencies observed during the cold weather, attention should be called to the cracks in the wall between the settling basin and the filters, the effect of which first became noticeable in the effluents about the middle of November, 1897. At this time an effort was made to repair these cracks by closing them on the settling basin side, and it was then believed that this attempt was practically successful. In June, 1898, however, a small leak was again noticed. This time a small trough was built out under the opening, so that the water was compelled to pass out into the sand, instead of down along the wall. After this no trouble was noticed. Danger from cracks of this kind is lessened by placing the filter sand on the bottom for a short distance around the walls, instead of carrying the gravel and broken stone out close to the wall. But much safer, also, is that construction which places the settling basin at some distance from the filters, so that there is a barrier more efficient than a concrete wall between polluted and purified water. It is probable, however, that the lower bacterial efficiency in the winter was due in some degree to the disturbing influences of low temperature, especially upon the sand surface when exposed for scraping, upon these open and unprotected filters.

Recent Data. Through the kindness of the former Director of Public Works, Mr. E. M. Bigelow, M. Am. Soc. C. E.; the Superintendent of the Bureau of Water, Mr. A. B. Shepherd, and of Mr. Wm. R. Copeland, now Bacteriologist-in-charge, the writer is enabled to present, in Table No. 1 A, a summary of results obtained since September, 1898, by the Bureau of Water. The results for the winter months are in line with those in Table No. 1, and show markedly the influence of the cold weather.

In June, 1899, about one foot in depth of the top sand then remaining in the filters was removed, and new sand was placed in them to a depth of three feet; then about 9 inches of the old material was replaced, bringing the sand surface about to the original grade. For this reason the average results for the first six days of June, 1899, are reported separately from those for the last nineteen days. However, the average for the year 1899 was obtained by using an average for June, giving the proper weight to the duration in time of each group of results.

After August 23, 1899, five baffle walls were used in one-half of the settling basin, causing the water applied to Filter No. 2 to travel in a horizontal tortuous course, and thus gave a more complete displacement.

TABLE No. 1[illegible]A.

Average of Daily Results with Sand Filters, by Months.

(After August, 1898.)

Months.	Hours in Operation per Day.		Rates of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
	No. 1.	No. 2.	No. 1.	No. 2.	Raw Water.	Settled Water.	Effluents. No. 1.	Effluents. No. 2.	Raw Water	Settled Water.	Effluents. No. 1.	Effluents. No. 2.	No. 1.	No. 2.
1898.														
September	23.4	22.1	3.04	4.67	0.04	0.03	0.004	0.006	18,100	17,500	54	120	99.70	99.34
October	23.8	21.9	2.90	4.62	0.11	0.09	0.003	0.003	35,200	34,600	100	140	99.72	99.60
November	23.7	20.7	3.09	2.61	0.10	0.10	0.010	0.009	15,700	12,000	190	325	98.79	97.93
December	22.0	22.7	2.85	2.73	0.11	0.08	0.005	0.006	22,400	19,400	940	850	95.80	96.21
Average, 1898	23.2	22.7	2.92	3.35	0.17	0.11	0.008	0.009	15,700	13,600	197	233	98.75	98.58
1899.														
January	24.0	23.3	3.06	3.01	0.15	0.13	0.016	0.012	29,700	38,300	506	360	98.30	98.79
February	22.4	23.4	2.97	3.10	0.15	0.10	0.008	0.007	12,600	16,200	380	340	96.99	97.31
March	23.3	23.4	3.15	2.95	0.21	0.18	0.021	0.021	17,400	16 800	179	282	98.97	98.38
April	23.3	23.3	3.17	3.08	0.10	0.09	0.016	0.012	7,000	7,110	65	64	99.07	99.09
May	22.4	23.5	2.99	3.12	0.14	0.13	0.008	0.012	10,000	9,810	114	128	98.86	98.72
June—6 days	23.2	24.0	3.07	3.12	0.18	0.09	0.012	0.010	5,730	3,840	79	106	98.62	98.15
June—19 days	24.0	23.9	2.02	2 00	0.16	0.13	0.016	0.016	13,600	4 900	1500	1010	89.00	92.60
July	22.2	22.8	2.40	2.44	0.20	0.18	0.011	0.015	8,250	4,640	218	128	97.36	98.45
August	23.2	23.4	2.92	2.89	0.27	* 0.24 0.17	0.015	0.016	20,400	* 14,900 18 700	56	86	99.73	99.58
September	23.2	23.2	2.93	2.94	0.16	* 0.15 0.13	0.010	0.009	23,600	* 15,800 16,100	56	44	99.76	99.81
October	23.2	23.3	2.97	2.97	0.04	* 0.04 0.04	0.002	0.002	41 500	* 29,900 26,500	48	45	99.88	99.89
November	21.7	21.7	2.68	2.64	0.15	* 0.14 0.13	0.006	0.005	13,500	* 10,900 16,200	405	79	97.00	99.41
December	23.0	22.6	2.64	2.79	0.18	* 0.17 0.14	0.012	0.013	15,000	* 13,300 12,400	121	165	99.19	98.90
Average, 1899	23.0	23.1	2.85	2.84	0.16	0.13	0.012	0.012	17,600	15,400	272	207	98.45	98.82
January, 1900	21.7	21.1	2.44	2.34	0.19	* 0.14 0.13	0.012	6.014	22,100	* 27,800 21,400	463	535	97.9	97.58

Notes.—Settled water was applied to both filters all the time, except for occasional days.
Averages of both periods in June, and, for records starred, the average of both results, were used in computing yearly averages.
* First result given where starred refers to water applied to Filter No. 1, and second result to that applied to Filter No. 2.

Asbestos pulp was used on the surface of Filter No. 2 in different quantities from October 27 to November 12, 1898. From November 2 to December 13, 1898, sulphate of alumina was added to the applied water, as it entered the settling basin, at rates varying from $\frac{1}{4}$ to 1 grain per gallon. Neither of these special experiments was productive of conclusive evidence, as the time of trial was limited, and the facts are recorded here solely in order that the full history to accompany Table No. 1 A may be given. Fig. 6 shows how the asbestos pulp may be rolled up like a carpet when dried to the proper degree.

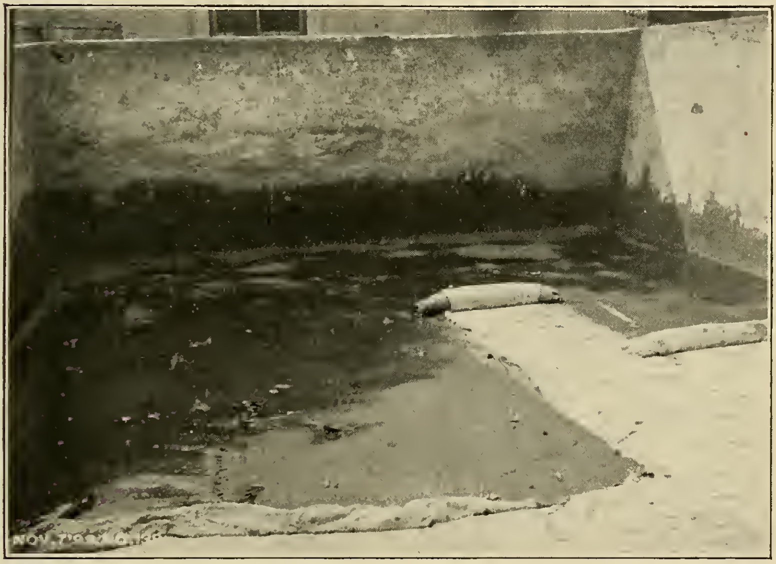


FIG. 6. SAND FILTERS, REMOVAL OF ASBESTOS FILM.

Periods between Scrapings. The following tables, No. 2 and No. 2 A, contain the results of the runs between scrapings, the first until September, 1898, and the second from that time to January, 1900. The results for Filter No. 1, in Table No. 2, differ slightly from the summaries given in the report of the Filtration Commission, as the figures have been entirely recalculated from the original records, to give the result at the exact time that the loss of head reached 4 feet:

Not all the periods have been included in Table 2 A. The records are omitted in cases where special tests with asbestos were conducted, and where, for experimental purposes, very small depths of sand were removed at a scraping, which created,

TABLE No. 2.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

Number of Period.		Number of Days.		Average Turbidity. Applied Water.		Average Turbidity. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
1	2	22.8	14.7	0.19	0.27			44 6	30.8	0.04	0.04
2	3	45.7	37.1	0.06	0.06			135.9	111.3	0.06	0.04
3	4	32.9	37 0	0.03	0.04			98.8	111.8	0.05	0.06
4	5	17.9	4.2	0.20	0.54			53.1	12.1	0.05	0.07
—	6	—	11.0	—	0.24			—	32.7	—	0.09
5	7	18.2	21.4	0.15	0.16			54.1	51.0	0.13	0.05
6	8	12.1	17.0	0.07	0.18			36.0	34.1	0.03	0.04
7	9	12.1	9.4	0.21	0.14		0.022	35.9	18.6	0.05	0.10
8	10	11.2	29.1	0.10	1.10	0.012	0.011	33.1	69.1	0.10	0.06
9	11	30.5	18.6	0.10	0.13	0.012	0.009	91.3	56.8	0.07	0.06
10	12	26.4	4.2	0.21	0.98	0.014	0.046	79.8	12.3	0.12	0.13
—	13	—	14.4	—	0.14	—	0.013	—	43.8	—	0.07
11	14	32.8	26.4	0.06	0.08	0.002	0.002	99.2	81.1	0.07	0.07
12	15	33.3	23.8	0.10	0.21	0.014	0.015	100.2	72.1	0.07	0.10
—	16	—	16.1	—	0.22	—	0.008	—	48.4	—	0.11
13	17	30.0	17.2	0.12	0.15	0.007	0.013	90.4	69.3	0.09	0.06
14	18	30.8	22.5	0.21	0.07	0.003	0.001	92.8	114.4	0.13	0.07
—	19	—	17.7	—	0.28	—	0.012	—	89.5	—	0.12
Average............		25.5	19.0	0.12	0.15	—	—	74.7	58.8	0.08	0.07

TABLE No. 2 A.

QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

(After August, 1898.)

Number of Period.		Number of Days.		Average Turbidity. Applied Water.		Average Turbidity. Effluent.		Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet, Removed at Scraping.	
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
16	20	29.8	22.3	0.05	0.09	0.006	0.018	72.3	112.3	0.05	0.09
17	21	30.6	33.8	0.06	0.03	0.001	0.002	71 7	179.1	0.09	0.09
18	—	19.8	——	0.10	——	0.014	——	64.0	——	0.07	——
19	27	10.2	13.4	0.05	0.04	0.004	0.000	33.9	41.6	0.10	0.24
20	28	16.2	13.4	0.04	0 09	0.000	0.002	51.2	41.2	0.09	0.09
21	—	9.9	——	0.20	——	0.016	——	30 7	——	0.15	——
22	29	34.1	28.1	0.12	0 14	0.013	0.014	100.6	86.6	0.11	0.17
23	30	12.3	27.3	0.05	0.06	0.005	0.006	39.4	84.1	0.09	0.08
24	31	30.1	30.2	0.20	0 21	0.022	0.019	96.3	94.0	0.24	0.12
25	32	31.3	36.1	0.11	0.12	0.020	0.016	98.5	109.7	0.09	0.06
26	33	23.2	38.2	0.04	0.10	0 005	0.011	76.3	121.8	0.04	0.06
27	—	15.0	——	0 11	——	0 011	——	18.4	——	0.04	——
28	34	19.4	19.1	0.16	0.16	0 012	0.015	38.3	37.8	0.05	0.06
29	35	17.0	18.0	0.14	0.17	0.012	0.016	48.0	48.9	0.19	0.08
30	36	23.0	23.0	0.21	0.23	0.016	0.019	70.1	73.7	0.06	0.08
31	37	23.0	28.0	0.22	0.12	0.012	1.010	69.7	82.6	0.11	0.10
32	38	38.0	36.5	0.06	0.05	0.004	0.003	118.2	107.4	0.06	0.04
33	39	10.0	6.0	0.12	0.13	0.002	0.001	29.4	20.9	0.03	0.02
34	40	9.6	10.0	0.09	0.09	0.007	0.004	31.0	30.6	0.05	0.05
35	41	9.0	11.0	0.13	0.12	0.007	0.007	26.4	32.5	0.04	0.05
36	42	8 2	10.5	0.06	0.06	0.008	0.008	23.0	26.4	0.03	0.04
37	43	5 2	3.5	0.25	0.33	0.007	0.017	14.3	9.5	0.08	0.04
Average		22.5	26.3	0.11	0.11	0.010	0.010	64.6	87.2	0.10	0.10

NOTES.—During periods 22–26, inclusive, for Filter No. 2 asbestos was used on the surface.

For the last five periods of each filter small depths of sand were removed at scrapings, which caused an initial loss of head greater than one foot and decreased the lengths of the periods. The results of these periods were not used in computing the averages.

for the next run, a large initial loss of head, greater than one foot.

In Tables No. 2 and No. 2 A, it will be noticed that there appears to be some relation between the length of period, or

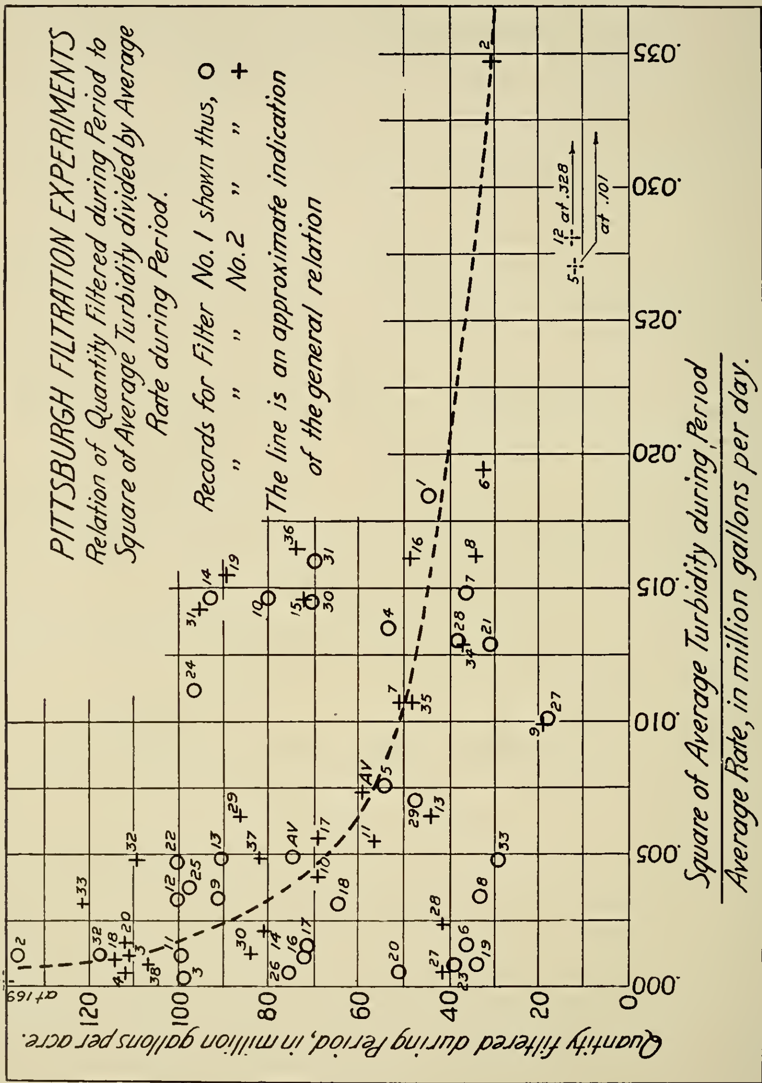


FIG. 7.

quantity filtered between scrapings, and the average turbidity for the period. In general, the more turbid the water the less the length of the period and the less the quantity filtered, but the relation is not an exact one. In Fig. 7 the results in Tables No.

2 and No. 2 A have been plotted, using, as ordinates, the quantity filtered, and, as abscissæ, the square of the average turbidity during the period, divided by the average rate. It will be seen that many points are at some distance from the average line, yet there does seem to be some general relation.

It may be that the storage of suspended matter in the sand, as evidenced by the turbidity of the effluent long after the muddy water has passed by, affects the length of the period to some degree. No doubt the length of the period is also somewhat affected by the variation in the temperature of the applied water; the low temperature in winter requiring a greater loss of head than the warm weather to filter the same quantity. It is probable, however, that these factors are obscured by the errors in determining the effect of the water upon the filters, in regard to depositing a clogging layer, but, more than anything else, the diagram teaches us that a more accurate method of observing turbidity is needed.

The question of this relation is an interesting and even an important one; for if, by continuous and systematic observations of the turbidity of a source of supply, the probable quantity of water that will be filtered between scrapings can be determined, the largest item of the cost of maintenance of slow sand filters may be accurately estimated without waiting for the actual trial of the filters.

TABLE No. 3.

Average Results of Chemical Analyses of Samples Collected from the Allegheny River and Sand Filters during the Thirteen Months Ending August 31, 1898.

(Parts per 100,000.)

Constituents.	River Water.	Outlet from Settling Basin.	Effluents.		Percentage of Constituents Removed.	
			No. 1.	No. 2.	No. 1.	No. 2.
Color	0.29	0.27	0.09	0.09	69	69
Nitrogen, as—						—
Albuminoid ammonia	0.0116	0.0108	0.0063	0.0064	46	45
Free ammonia	0.0019	0.0019	0.0016	0.0016	16	16
Nitrites	0.0000	0.0000	0.0000	0.0000	—	—
Nitrates	0.0684	0.0641	0.0715	0.0647	—5	5
Chlorine	2.19	2.08	2.06	2.02	6	8
Total solids	15.9	13.1	12.1	12.1	24	24
Suspended matter	4.2	1.3	0.0	0.0	100	100
Total hardness	3.58	3.69	4.72	4.83	—32	—35
Alkalinity	2.89	3.07	4.13	4.22	—43	—46
Sulphuric acid	1.44	1.38	1.44	1.44	—	—
Iron	0.052	0.060	0.016	0.018	69	65

Chemical Results. Table No. 3 gives the average results, for the whole period, of the chemical analyses of samples of water collected (1) from the Allegheny River, (2) from the outlet from the settling basin and (3) from the sand filter effluents; together with the percentage of chemical constituents removed. Tables 12 A to 12 E, at the end of this paper, contain the monthly averages of the results of the chemical analyses and the average summaries for different periods.

WARREN FILTER.

This filter was located in the western portion of the filter building. A plan will be found in Fig. 8, and an elevation in Fig. 9. The system consisted of a settling basin, having baffle walls and a circular tank, or filter proper, which contained the filter sand and the agitating, washing and regulating devices.

Settling Basin. The capacity of the settling basin was about 11,200 gallons, which gave, if complete displacement were accomplished, a period of about fifty minutes for the water to pass from one end to the other when the filter was operated at a rate of 120,000,000 gallons per acre daily. Just before the water entered the settling basin it was measured by a meter, and then, at the entrance, was controlled by a butterfly valve, which was attached to a float on the surface of the basin. Next the water passed through a propeller, which operated the revolving coagulant pump or tympanum on the platform above.

Coagulant. The solution of coagulant was introduced as the water passed the propeller. The average composition of the sulphate of alumina, which was the coagulant used in both the Warren and the Jewell Filters, was:

	Parts of Weight.
Alumina oxide, soluble in water	17.18
Sulphuric acid	38.66
Iron oxide	0.00
Material insoluble in water	0.24

The coagulant solution was dissolved in two tubs, placed on top of the settling basin and was allowed to flow, first from one and then from the other, into the tank in which the tympanum was placed. The inner end of each arm of this pump was connected to one of a series of six tubes placed in the hub and parallel to the shaft. As the pump revolved each arm in turn was filled. As the arm became elevated the solution passed down into the hub, out into a lead cup on the side of the tank and thence to the settling basin below.

The elevation of the solution in the pump tank was kept as nearly constant as possible by rubber float valves. It was found, however, that this method was not entirely satisfactory, as the rub-

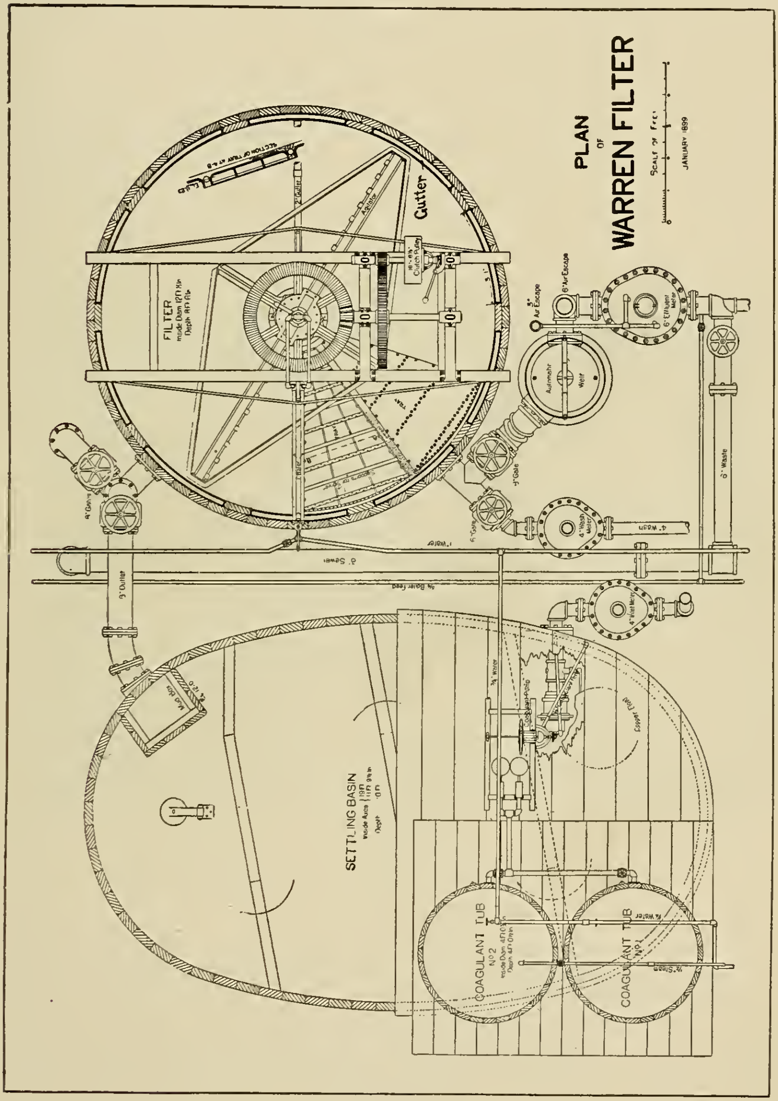


Fig. 8.

ber valves frequently became clogged. Also, when a new solution was first used the higher elevation of the liquid in the pump tank, due to the pressure from a full tub above, caused much more coagulant to be added to the applied water than when the solution in the

upper tub had nearly run out. It was endeavored to remedy this by opening the valve from the coagulant storage tub a little only at the

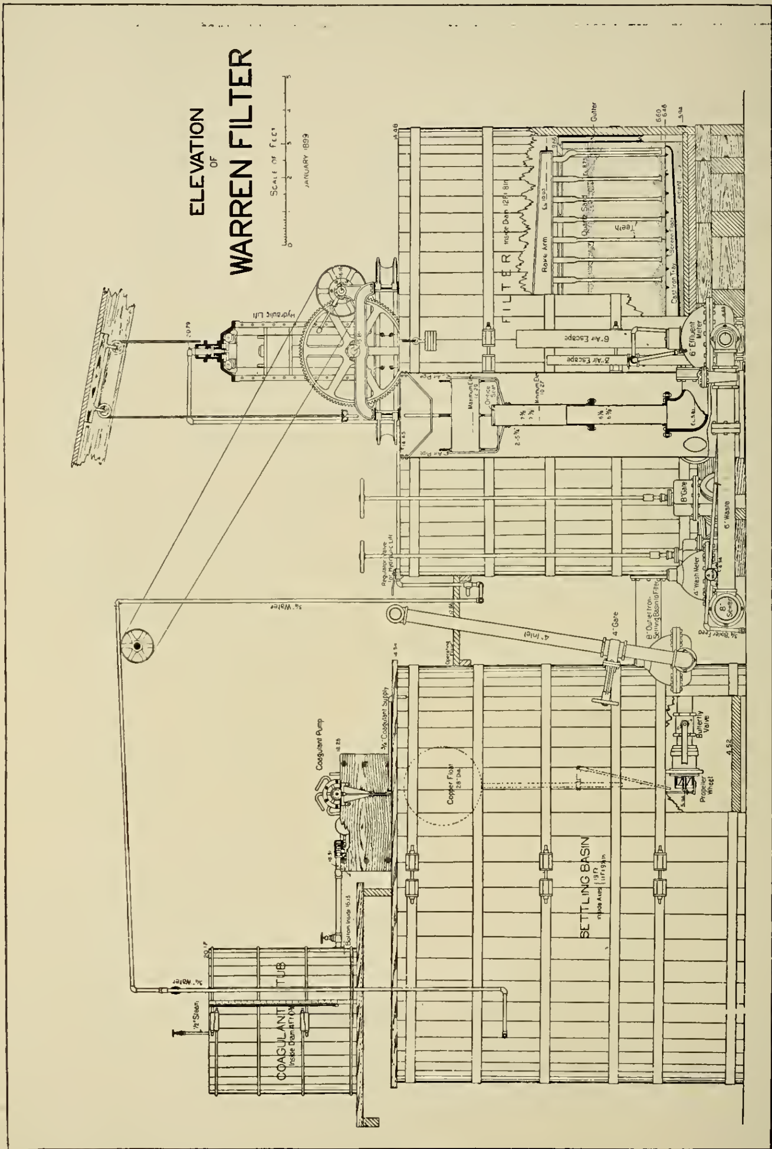


Fig. 9.

beginning, and gradually increasing this opening as the tub became empty. Even with this care, the rate of application of the coagulant solution was not constant.

Without quoting in detail the tables which are published in the report, the following brief summary, contained in Table No. 4, will show the nature and amount of this variation, both for the Warren and Jewell Filters. It must be remembered, however, in studying this table that it is more difficult to apply a coagulating liquid accurately on a small than on a large scale.

Filter. The filter proper was composed of a circular tank with a sand area of 118 square feet. On the bottom, inside, were placed segmental iron troughs set in concrete, which served as a support for a brass strainer floor and also as collectors for the filtered water. From the bottom of the tank, and connected directly with the inlet

FIG. 10. WARREN FILTER, DISMANTLED INTERIOR SHOWING CENTRAL WELL, SEGMENTAL TROUGHS, VERTICAL GUTTERS AND ONE 2-INCH CONNECTING PIPE.

pipe, was a central well, which extended up through the filter floor and above the sand surface. Communicating with this well and passing between the collecting troughs were ten 2-inch horizontal pipes, which were connected with vertical iron gutters placed around the filter inside the staves.

The inlet water from the settling basin was distributed over the sand surface from the central well, and from the vertical circumferential gutters. Fig. 10 shows the central well, circumferential gutters and 2-inch connecting pipes, all at the time the filter was being dismantled.

The sand used was crushed quartz, which was angular at first, but the sharp edges became rounded after some months of use. The effective size was 0.63 mm., and the uniformity coefficient was 1.1. The sand was 2.3 feet deep, and rested directly on the brass strainer floor, which contained 292,900 holes, each being 0.024 inches in diameter.

Regulating Weir. After passing through the sand the water was collected in the radial troughs, and passed from a central annular compartment to the chamber of the so-called automatic weir. The principle of this device was that of a changeable orifice plate in a sliding pipe attached to a large copper float, and its object

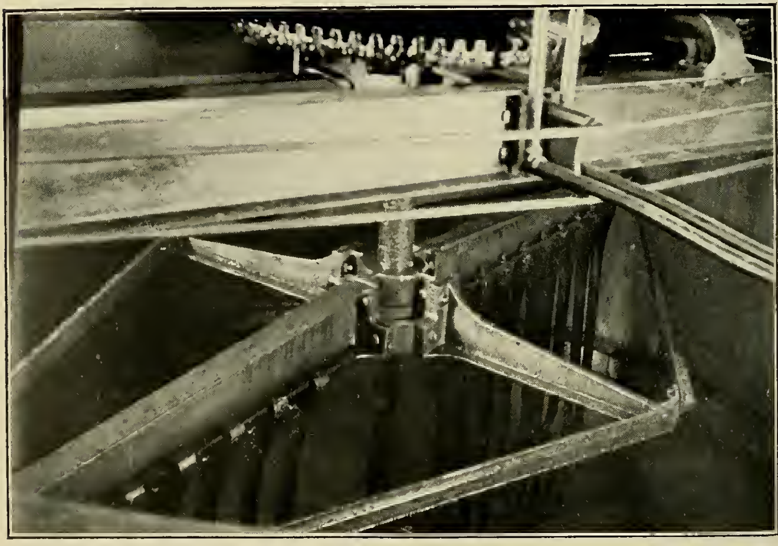


FIG. 11. WARREN FILTER, AGITATING DEVICE.

was to maintain the same head upon the orifice. In fact, however, the quantities filtered were somewhat less before washing than immediately after. The extent of the variation for some representative periods is given in Table No. 5. This controlling weir was the cause of overregistration of the effluent meter, due to the presence of air needed to operate the weir properly. This error was as large as 13 per cent., and varied in the beginning, but by the application of air escape pipes at proper places between the weir and the meter this error was reduced and maintained at 4 per cent.

Washing. Filtered water for washing was furnished by two duplex steam pumps, size 12 x 7 x 18 inches, which drew the water

from a large effluent tank under the building. The wash water was measured by a meter, then entered the filter by the effluent pipe and passed up through the screens and sand in the opposite direction to that of the current of water when filtering. As the dirty water flooded above the sand, it overflowed down the central well and the circumferential gutters, and thus passed out through a waste pipe to the sewer.

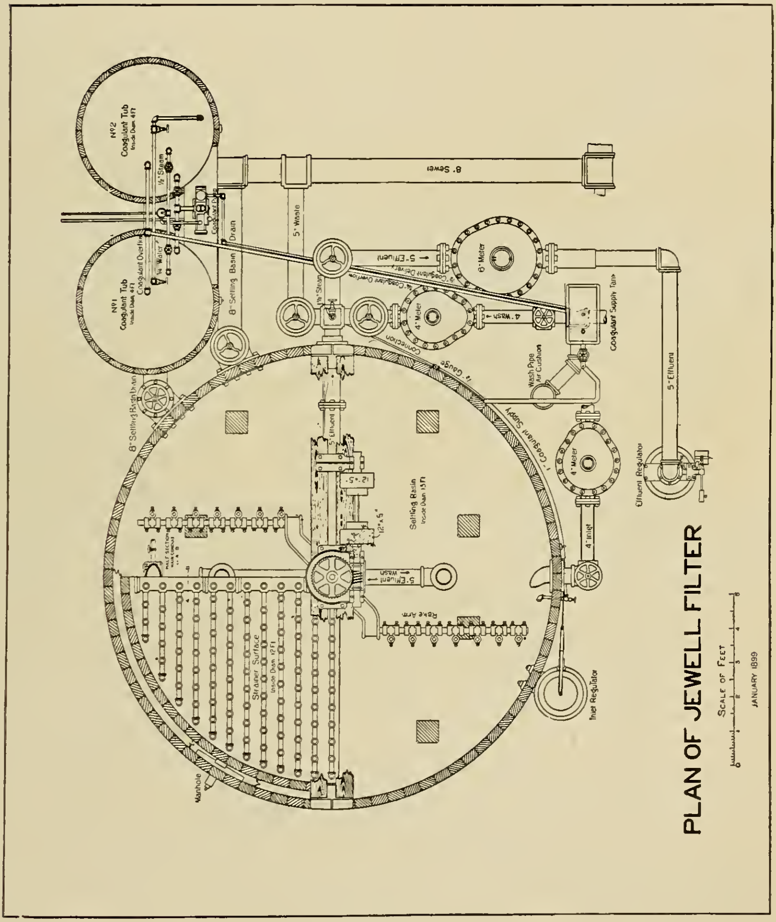


FIG. 12.

Agitator. At the time of washing the agitator was made to rotate through the sand at the rate of three turns to the minute, thus stirring the mass to the bottom. This device consisted of two horizontal arms, 180° apart, connected to a central vertical shaft, which was turned by gearing. The power in this case was furnished by a small engine on the floor. On each of the arms were

nine teeth, which cleared the strainer bottom by 0.14 feet when the agitator was in the lowest position. The device was raised and lowered by means of a hydraulic lift placed on top of the central shaft, the whole being supported upon I beams placed on top of the

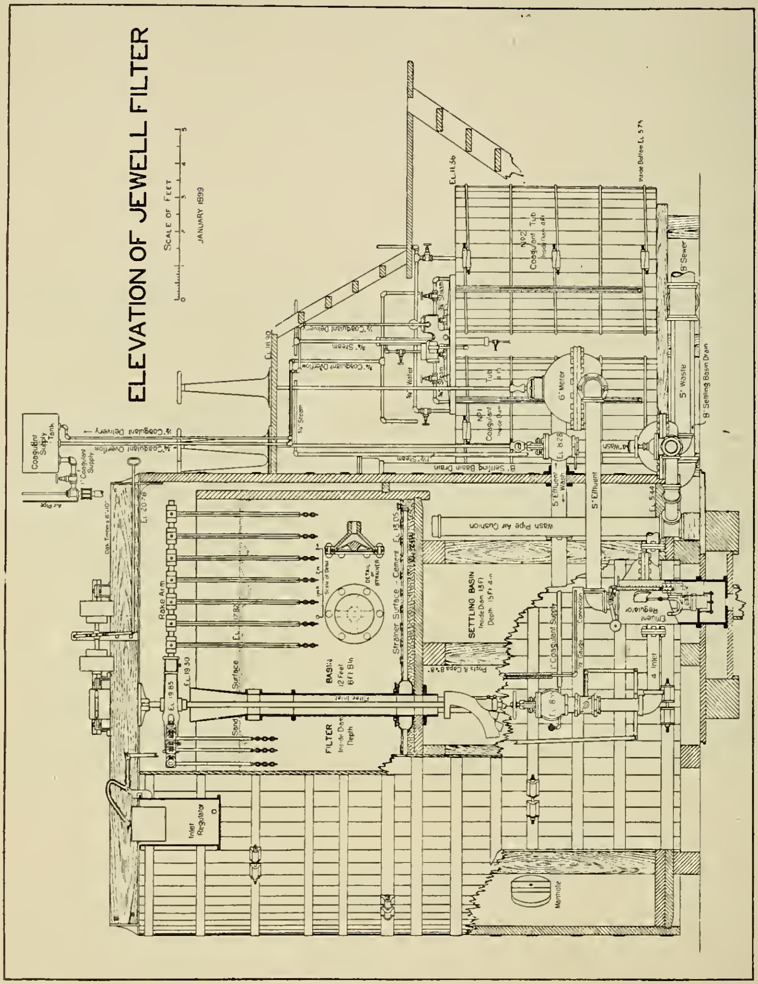


FIG. 13.

filter. Fig. 11 shows the rakes extending down from the arms and just touching the sand surface.

JEWELL FILTER.

This filter was located in the central portion of the filter building. A plan will be found in Fig. 12, and an elevation in Fig. 13. The plant consisted of a settling basin in the bottom portion of an

outside tank, and an open filter in a smaller tank placed within and above the former.

Settling Basin. The capacity of the basin was about 6600 gallons, which was equal to 35 minutes' flow when the filter was operated at the rate of 105,000,000 gallons per acre daily. The water was admitted to the basin through a curved deflecting pipe, which caused a whirling motion as it passed upward to the filter above.

Coagulant. The preparation of the coagulant was the same as for the Warren Filter. The solution was lifted by a small steam pump from either of the two tubs to a small tank above the filter, in which a constant head was maintained by pumping an excess and allowing the surplus to run back to the original tub. This method aided, somewhat, toward keeping the solution mixed in the tub. From the tank the solution passed through a standard orifice and pipe to the settling basin, which it entered near where the applied water passed in. Changes in the amount of coagulant supplied were made by changing the orifices. This method of application was somewhat more exact than that used with the Warren Filter, as the figures given in Table No. 4 indicate, but incrustation on the edges of the orifice changed the area and thus caused errors.

TABLE No. 4.

VARIATION IN THE APPLICATION OF COAGULANT TO MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Amount of Sulphate of Alumina Used, in Grains per Gallon. For Duration of Thirty Minutes. Highest.	Lowest.	Average for Duration of Experiment.	Percentage of Variation from the Average. Highest.	Lowest.
1	April 14	Warren	0.91	0.39	0.55	+66	−29
2	" 14	Jewell	0.53	0.26	0.34	+56	−24
3	June 10	Warren	2.48	0 80	1.30	+91	−38
4	" 23	"	3.96	0.66	2.19	+81	−70
5	" 23	Jewell	2.48	1.05	1.90	+31	−45
6	August 12	Warren	3.86	0.91	1.57	+146	−42
7	" 12	Jewell	2.09	0.65	1.11	+88	−41
Average........................			2.33	0.67	1.28	+82	−48

Filter. The filter proper was placed above the settling basin, and contained 4.8 feet in depth of round-grained yellow beach sand, of an area of 113 square feet. Different sizes of sand were introduced by the company from time to time. The uniformity coefficient varied from 1.3 to 1.7, and the effective size from 0.33 mm. to 0.47 mm. The water from the settling basin passed up through a central well and overflowed the sand surface. After passing down through the sand the filtered water was collected in 443

screens, which were clamped over openings in the collecting pipes. The holes in the screens were 0.025 inches in diameter. Fig. 14 shows the screen heads on the pipes, together with the surrounding sand, over a portion of the bed. These pipes drained to collecting conduits which entered the 5-inch effluent pipe leading to the outside. Just outside the filter there was placed a cross connection, which allowed water to pass either through the effluent meter and regulator to a tank under the floor or to the sewer. This connection also permitted the introduction of wash water in a reverse direction for cleansing the filter.

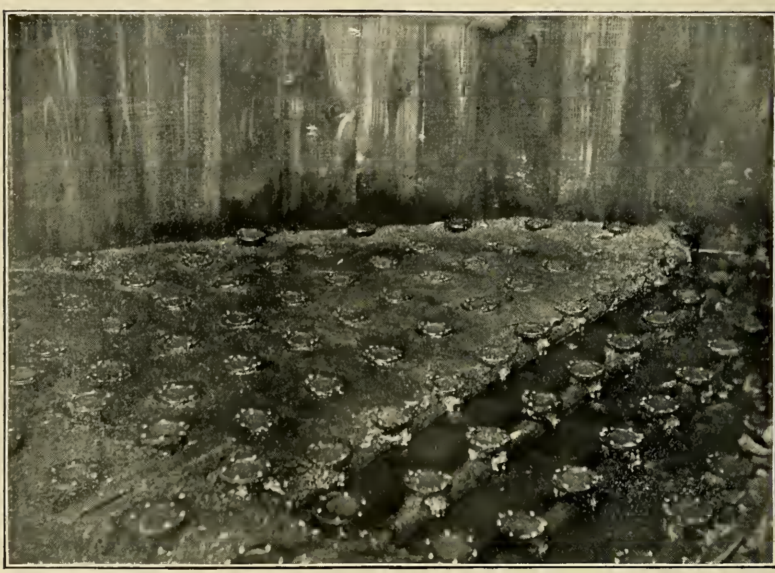


FIG. 14. JEWELL FILTER, SCREEN HEADS ON COLLECTING SYSTEM.

Controller. This device was intended to maintain a constant head upon an orifice plate placed in the bottom by allowing such water as rose above a certain level to flow over into a cup. This cup was attached to a lever arm, the inner end of which operated a butterfly valve in the pipe which discharged directly over this orifice. A view of the controller is given in Fig. 15. The efficiency of this device was tested from time to time, and the variations of the flow, as shown by representative tests, are given in Table No. 5. In this connection, however, reference should be made to a new form of controller recently devised for this use, which is said to give satisfactory results.*

*See paper by E. B. Weston, C.E., on "Mechanical Filtration," *Journal of New England Water Works Association,* June, 1900, page 343.

TABLE No. 5.

VARIATIONS IN THE RATES OF FILTRATION WITH MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Quantity Filtered, in Gallons. For Duration of Thirty Minutes. Highest.	Lowest.	Average for Duration of Experiment.	Percentage of Variation. From the Average. Highest.	Lowest.	Total between Extremes.
1	April 14	Warren	8670	6380	7550	+15	—15	30
2	" 14	Jewell	6420	5210	5740	+12	—9	21
3	June 10	Warren	7720	4520	5780	+34	—22	56
4	" 23	"	7110	5360	6330	+12	—15	27
5	" 23	Jewell	6290	5260	5780	+9	—9	18
6	August 12	Warren	9260	5170	7360	+26	—30	56
7	" 12	Jewell	8580	2680	5550	+55	—52	107
Average			7720	4940	6300	+23	—22	45

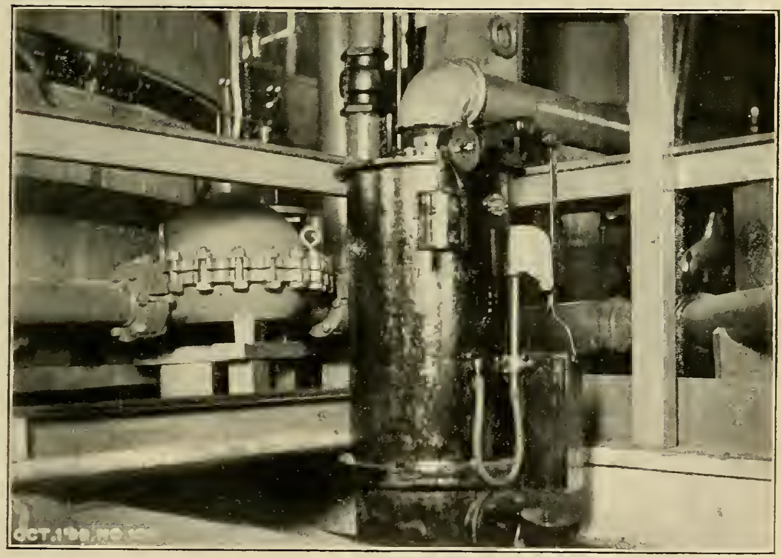


FIG. 15. JEWELL FILTER CONTROLLER.

Washing. This work was done in the same general manner as with the Warren filter, but in this case the dirty water overflowed into the annular space between the inner and outer tanks, and thus away to the sewer. The agitating device also was somewhat different. There were two sets of arms and rakes, the larger rakes being 4 feet long and fastened to arms reaching from the center across the filter bed and placed 180° apart. The shorter arms had only three rakes; were placed at right angles to the others, and stirred the sand close to the central well not disturbed by those on the longer arms. While the filters were operating these rakes lay

upon the sand of the filter, but when the power for agitating the bed was applied the arms started to revolve and forced the rakes to a vertical position and down into the sand. When the operation of washing was discontinued the arms were made to revolve in the opposite direction, and the rakes were thus trailed out on top of the bed again and left in a nearly horizontal position. The device made about seven turns per minute. Fig. 16 shows the rakes nearly pulled out to the surface of the sand.

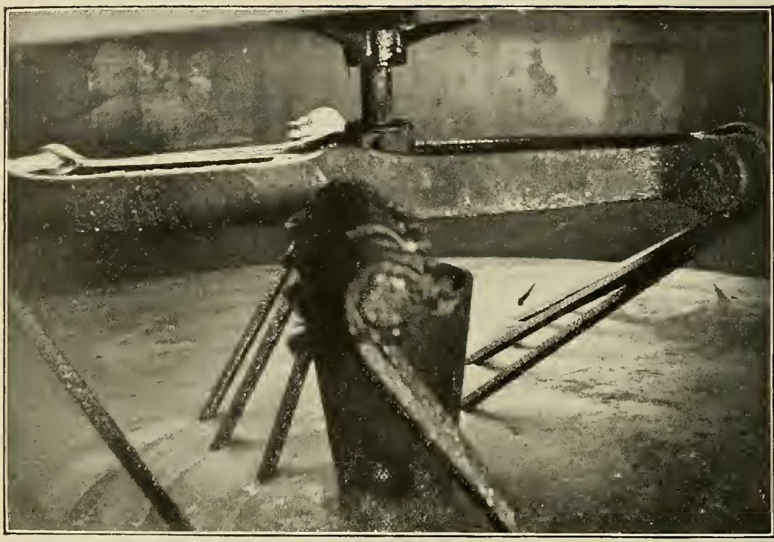


FIG. 16. JEWELL FILTER, AGITATING DEVICE.

At certain times, instead of washing the Jewell Filter bed, recourse was had to trailing the rakes around upon the surface of the bed in the direction opposite to that when washing, the water remaining upon the surface. This method made furrows about 2 inches deep in the sand. When the bed was new or had recently been thoroughly cleansed by the boiling solution of soda ash, this method was quite effective for once or twice after a washing, to restore the head lost and for lengthening the time between washings. But at other times its benefit was less evident.

MECHANICAL FILTERS IN GENERAL.

Effect of Washing. An interesting factor in mechanical filtration is the effect which washing the filter sand has on the character of the effluent. The results in Table No. 6 have been deduced from observations taken at random under the natural conditions of the

work of both filters. In general, the number of bacteria immediately after washing was about five times as great as before, and quite often the turbidity of the effluent was noticeably greater. It was observed that under normal conditions—that is, with applied water of about the average muddiness and using, directly after washing, the same amount of coagulant as was ordinarily used to

TABLE No. 6.

BACTERIAL EFFICIENCY WITH MECHANICAL FILTERS BEFORE AND AFTER WASHING.

Calendar Date, 1898.	Name of Filter.	Average Bacteria per Cubic Centimeter in Effluent. For Twenty-four Hours. Number.	For One Hour before Washing. Number.	For One Hour before Washing. Per Cent. of Average for Twenty-four Hours.	For Twenty Minutes after Washing. Number.	For Twenty Minutes after Washing. Per Cent. of Average for Twenty-four Hours.
March 31	Warren	69	32	46	326	473
April 1	"	69	54	78	271	393
" 1	"	220	294	134	387	176
April 2	Warren	220	126	57	444	202
" 14	"	79	73	92	160	203
" 19	Jewell	96	55	57	338	352
April 20	Warren	32	14	44	233	729
" 20	Jewell	96	59	61	329	353
" 21	Warren	6	4	67	38	633
April 23	Warren	15	8	53	52	347
" 24	"	15	51	340	47	313
May 3	Jewell	36	29	81	175	486
May 6	Jewell	28	6	21	205	732
June 2	Warren	105	79	75	516	491
" 2	"	100	60	60	469	469
June 6	Warren	17	6	35	21	124
August 12	"	165	11	7	1,180	715
" 13	"	165	166	101	549	333
Average...		85	63	74	319	375

secure good results—this poor condition of the effluent lasted about twenty minutes. If large quantities of coagulant were used directly after washing—that is, considerably more than the average amount necessary for good results with the given condition of the water—these higher numbers of bacteria obtained for a short time only, say five or ten minutes, after which they were greatly reduced.

Effects of Using Different Quantities of Coagulant. During the months of May and June, 1897, special experiments were made to determine the effect of using (1) large quantities of coagulant and (2) no coagulant.*

*For details, see "Report of Filtration Commission," pages 170, 171.

In general, after using a normal amount of coagulant the effect of not using any was apparent by a somewhat turbid effluent about forty-five minutes after shutting off the supply of coagulant. After two hours the number of bacteria was from one-half to about the same number as in the applied water, and the effluent was very much the same in appearance as the applied water. The time needed for a filter to recover itself after operation without coagulant, by using a large amount (in this particular case 2.75 grains per gallon), was also about two hours.

Whirling Motion. Mr. E. B. Weston, in his very interesting paper on "Mechanical Filtration," presented to the New England

TABLE No. 7.

EFFECT OF WHIRLING MOTION UPON SETTLING WITH COAGULATION.

Month, 1898.	Bacteria per Cubic Centimeter.		
	Applied Water.	Settled Water.	
		Warren.	Jewell.
February	9,430	7,130	7,190
March	11,750	6,160	5,780
April	5,000	3,360	3,620
July	16,800	10,900	10,900
August	15 100	7,550	7,780
Averages	11,600	7,020	7,050
Date, 1898.	**Amount of Suspended Matter. (Parts per 100,000.)**		
August 15	3 9	3.6	2.8
" 29	2.4	0 6	0.8
Averages	3.1	2 1	1.8
Ratio of Capacity of Settling Basin to Daily Quantity	--	0.0359	0.0244

Water Works Association, January 10, 1900,* has shown that by giving a whirling motion to the water entering the Jewell settling basin the precipitation of suspended and organic matter is considerably increased. So far as the writer knows, Table No. 7 gives the first published numerical data for cases where the same water was used, both with and without whirling. The quantities of coagulant added to the two filters are not sufficiently different to affect seriously the results and conclusions, but are, in general, larger for the Warren. It will be seen that the effect of the coagulation in each

Journal of New England Water Works Association, for June, 1900, pages 349, 358, 359.

settling basin is about the same, although the Warren has 50 per cent. greater capacity in proportion to the daily quantity. In this settling basin the water takes a somewhat winding but quiet course, while in the Jewell it is given a rapid whirling motion.

The quantitative and bacterial results obtained with the mechanical filters, tabulated by months, are given in Table No. 8. The averages of the chemical constituents of the applied water and of the effluents of the mechanical filters, also compared with those of the sand filters for the same seven months, are given in Table No. 9.

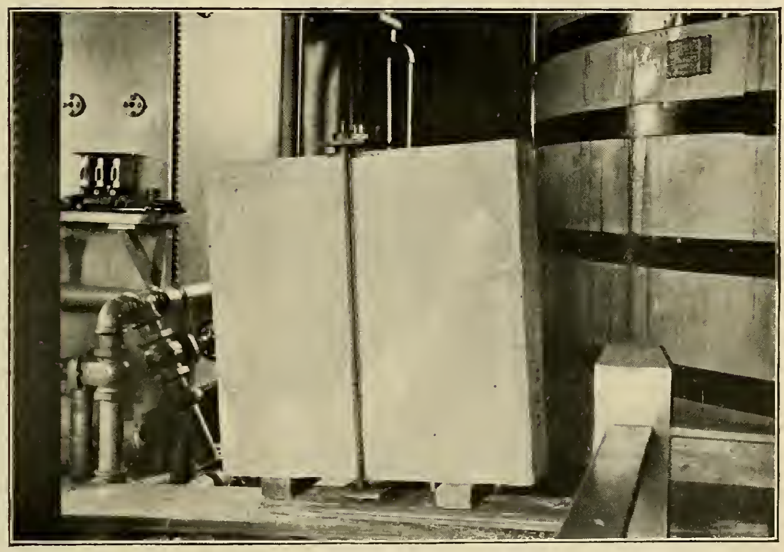


FIG. 17. WORMS TILE WITH FITTINGS.

WORMS TILE FILTER.

The process of water purification by the "Wormser" system, as tried at Pittsburgh, was two-fold: First a preliminary treatment by the addition of chloride of iron and removal of some matter by passage through broken stone, and, second, a filtration through the tiles.

Tiles. The tiles were made in Germany, and were composed of sand and broken glass baked in a mold. They were about 39 inches square and 4 inches thick. In the center of each there was a chamber of about $\frac{1}{2}$ cubic foot capacity, in which the water collected after filtering through the sides. Fig. 17 shows a view of a tile ready to be placed in the tank, and the method of making the pipe connection by gasket to the hole leading to the interior of the tile.

TABLE No. 8.

Average Daily Results of Mechanical Filters by Months.

Months, 1898.	Hours in Operation per Day.		Rate of Filtration in Million Gallons per Acre Daily.		Ratio of Washing Time to Operating Time in Percentage.		Per Cent. of Filtrate Used in Washing.		Sulphate of Alumina, Grains per Gallon.		Turbidity.			Bacteria per Cubic Centimeters.			Percentage of Bacteria Removed.	
											Applied Water.	Effluents.		Applied Water.	Effluents.			
	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.		Warren.	Jewell.		Warren.	Jewell.	Warren.	Jewell.
January	10.1	8.1	117	85	2.3	3.4	4.8	8.8	1.19	0.72	0.29 W. 0.16 J	0.001	——	19,550 W. 12,950 J.	950	1980	95.14	84.70
February	21.3	20.7	104	98	1.4	2.1	3.8	6.1	0.70	0.56	0.15	0.005	0.004	9 430	238	638	97.48	93.23
March	22.3	22.2	108	106	0.9	1.2	3.5	4.3	1.81	1.07	0.30	0.001	0.001	11,750	164	208	98.60	98.23
April	23.0	22.9	122	106	0.7	0.7	2.6	2.8	0.86	0.54	0.08	0.001	0.000	5,000	78	159	98.44	96.83
May	23.6	23.2	115	106	0.8	1.2	2.6	4.6	1.55	1.00	0.19	0.015	0.000	10,800	630	150	94.20	98.61
June	23.3	22.8	103	106	1.0	1.4	3.9	5.4	1.36	1.18	0.19	0.001	0.008	11,100	115	1450	98.96	86.90
July	19.5	22.2	119	103	1.4	1.8	5.1	7.6	1.46	1.31	0.11	0.003	0.008	16,800	320	345	98.10	97.95
August	23.2	22.9	137	103	1.5	1.5	5.1	6.3	1.76	1.35	0.36	0.016	0.000	15,100	290	260	98.08	98.28
Average, 6 months	22.1	22.3	115	104	1.1	1.4	4.0	5.3	1.32	0.97	0.20	0.004	0.002	11,500	201	293	98.25	97.45

Note.—During the month of May with the Warren Filter and the month of June with the Jewell Filter, special experiments with varying quantities of coagulant were made. Averages do not include these months, nor the month of January.

TABLE No. 9.

AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER AND SAND AND MECHANICAL FILTERS DURING THE SEVEN MONTHS ENDING AUGUST 31, 1898.

(Parts per 100,000.)

CONSTITUENTS.	River Water.	Effluents.				Percentage of Constituents Removed.			
		Sand Filters.		Mechanical Filters.		Sand Filters.		Mechanical Filters.	
		No. 1.	No. 2.	Warren.	Jewell.	No. 1.	No. 2.	Warren.	Jewell.
Turbidity		0.010	0.012	0.000	0.001	—	—	—	—
Color	0.26	0.07	0.07	0.03	0.03	73	73	88	88
Nitrogen, as—									
Albuminoid ammonia	0.0101	0.0054	0.0053	0.0047	0.0043	47	48	53	57
Free ammonia	0.0020	0.0018	0.0018	0.0019	0.0018	10	10	5	10
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000	—	—	—	—
Nitrates	0.0568	0.0642	0.0549	0.0550	0.0520	—13	3	3	8
Chlorine	1.87	1.84	1.77	1.76	1.65	2	5	6	12
Total solids	15.4	10.8	10.6	9.5	9.4	30	31	38	39
Suspended matter	5.3	0.0	0.0	0.1	0.1	100	100	98	98
Total hardness	3.21	4.31	4.33	2.96	2.89	—34	—35	8	10
Alkalinity	2.44	3.53	3.56	1.64	1.69	—45	—46	33	31
Sulphuric acid	1.15	1.15	1.15	1.86	1.59	—	—	—62	—38

Washing. The tiles were washed by a reverse current of filtered water, with a head of 19.5 feet above the centers of the tiles. In washing the tiles, care was taken to let on the wash water pressure slowly, and to maintain the flow uniformly. Nevertheless, as soon as the tiles became sufficiently clogged to produce a good effluent they all were broken, one after another, while being washed. Fig. 18 shows the line of breakage on two of the tiles, and gives an idea of the interior construction.

FIG. 18. WORMS TILES, BROKEN IN SERVICE.

Results. In Table No. 10 are presented the average bacterial results, by months, obtained with this system of filtration. It will be seen that the tiles themselves do not appear to have materially reduced the number of bacteria below those in the water flowing from the settling tanks, which had been treated with coagulant.

BOILER EXPERIMENTS.

The use of water for industrial purposes is an important consideration in Pittsburgh, or, indeed, in any large manufacturing city. It was therefore considered advisable to learn what the effect would be of clarifying and filtering the Allegheny River water prior to its use in boilers.

Three new 25 H. P. boilers were kindly loaned by the Oil Well Supply Company for the purpose of an experiment in this line. Boiler No. 1 was supplied with the effluent from the sand filters, No. 2 with the effluent from the mechanical filters and No. 3 with

TABLE No. 10.

Average Bacterial Results with Worms Tile Filter.

Month, 1897-98.	Applied Water.	Bacteria per Cubic Centimeter. Settled Water. Tank No. 3.	Effluents. Tile A.	Effluents. Tile B.	Effluents. Tile C.	Settled Water. Tank No. 4.	Effluents. Tile D.	Effluents. Tile E.	Effluents. Tile F.	Percentage of Bacteria Removed. Settled Water. Tank No. 3.	Effluents. Tile A.	Effluents. Tile B.	Effluents. Tile C.	Settled Water. Tank No. 4.	Effluents. Tile D.	Effluents. Tile E.	Effluents. Tile F.
First Test.																	
December....	14,430	9160	8010	5280	5960	12,260	4990	5430	4930	36.60	44.50	63.40	58.70	15.00	65.40	62 30	65.90
January.......	15,330	7680	3050	3360	2470	—	6550	4120	—	49.90	80.10	78.10	83.90	—	57.30	73.20	—
February.....	9,430	3290	740	800	1030	—	—	—	—	65.10	92.20	91.50	89.10	—	—	—	—
March.........	11,750	4790	460	630	790	—	—	—	—	59.20	96.00	94.60	93.30	—	—	—	—
Second Test.																	
June.........	12,000	339	690	470	500	410	510	470	470	97.20	94.30	96.10	95.80	96.60	95.70	96.10	96.10
July............	16,800	920	310	400	370	1,010	980	960	590	94.50	98.20	97 60	97.80	94.00	94.20	94.30	96.50
August.......	16,900	345	100	120	70	360	340	320	110	98.00	99.40	99 30	99.60	97.80	98.00	98.10	99.40
First Test.																	
Average ...	12,730	6230	3070	2520	2560	—	—	—	—	51.10	75.90	80.20	79.90	—	—	—	—
Second Test.																	
Average ...	15,200	535	360	330	310	600	610	580	390	96.50	97.60	97.80	97.90	96.10	96.00	96.10	97.40

Note.—Coagulant was applied to the water in Tank No. 3 all the time; but to the water in Tank No. 4 during June, July and August only.

the unclarified river water. When these boilers had been in service for about two and one-half months they were blown off hot. Samples of scale were collected, and an examination was made of the interior of each. The results of the chemical analyses of the scales are given in the following Table, No. 11:

TABLE No. 11.

Results of Chemical Analyses of Boiler Scale Samples, Collected September 17, 1898.

Items.	Parts by Weight.		
	Boiler and Sample Number.		
	1	2	3
	Water from Sand Filters.	Water from Mechanical Filters.	Water from River.
Calcium carbonate	53.21	27.42	3.34
Calcium sulphate	13.06	53.88	0.75
Magnesium carbonate	25.33	12.58	11.06
Sodium chloride	5.74	1.64	0.39
Iron and aluminum oxides	1.42	3.64	16.66
Insoluble matter	1.24	0.84	67.80
Totals	100.00	100.00	100.00

Scale. It will be seen that the scale from Boiler (No. 1), using the effluent from the sand filters, was composed largely of the carbonates of calcium and magnesium, which are not as troublesome as the sulphates. It was said that, by cooling down slowly, the formation of this kind of scale could have been, in a measure, prevented. It will be noticed, however, that the scale from Boiler (No. 2), using the effluent from the mechanical filters, was composed largely of sulphate of calcium, which is what would be expected from the chemical action caused by the addition of sulphate of alumina to the water. The scale upon Boiler (No. 3), using the unclarified river water, was soft, and composed largely of mud and insoluble matter, material which could have been largely removed by judicious blowing out from time to time.

The statement of the practical boiler mechanic who examined the interiors after the experimental use was that Boiler No. 3 was in the best condition. This problem, however, must be considered as by no means settled by such a limited experiment.

CHEMICAL ANALYSES.

On the next few pages will be found tables showing, by months, the average chemical results obtained from the river water and from the various effluents.

TABLE No. 12 A.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM ALLEGHENY RIVER AT BRILLIANT.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	June	—	0.0137	0.0006	0.0000	0.0175	2.40	14.1	—	7.65	—	1.40	—
"	July	—	0.0307	0.0034	0.0001	0.0106	3.13	26.9	11.1	5.84	6.08	1.33	0.184
"	August	—	0.0210	0.0023	0.0000	0.1050	2.03	9.0	1.0	5.41	4.05	0.86	0.007
"	September	0.37	0.0133	0.0019	0.0000	0.0650	2.70	13.1	—	5.03	4.63	1.82	0.063
1897	October	0.23	0.0120	0.0017	0.0000	0.0550	3.81	17.7	—	5.49	5.09	2.31	0.046
"	November	0.29	0.0152	0.0019	0.0000	0.0700	3.15	19.7	2.0	3.89	3.51	2.47	0.095
"	December	0.30	0.0111	0.0015	0.0000	0.1075	2.11	23.7	10.7	2.24	1.72	1.79	0.123
1898	January	0.28	0.0074	0.0016	0.0000	0.0885	1.53	15.3	4.8	2.09	1.48	1.43	0.112
"	February	0.21	0.0099	0.0020	0.0000	0.1425	1.46	11.9	1.4	2.59	1.73	1.24	0.059
"	March	0.24	0.0076	0.0015	0.0000	0.0487	1.29	14.0	4.3	2.72	1.75	1.18	0.040
1898	April	0.22	0.0077	0.0018	0.0000	0.0458	1.36	9.4	0.2	2.29	1.83	1.08	0.041
"	May	0.30	0.0164	0.0015	0.0000	0.0180	1.66	20.7	11.9	2.80	2.13	1.00	0.033
"	June	0.25	0.0085	0.0019	0.0000	0.0300	2.42	19.1	9.0	3.51	3.10	1.04	0.010
1898	July	0.27	0.0100	0.0027	0.0000	0.0694	2.47	13.1	1.4	4.53	3.41	1.55	0.020
"	August	0.31	0.0103	0.0024	0.0000	0.0435	2.42	19.5	8.8	3.99	3.15	0.93	0.020
Ave., 15 months		0.27	0.0130	0.0019	0.0000	0.0611	2.26	16.5	5.4	4.00	3.12	1.43	0.061
Ave., Aug., '97—Aug., '98.		0.27	0.0116	0.0019	0.0000	0.0684	2.19	15.9	5.0	3.58	2.89	1.44	0.051
Ave., Jan., '98—Aug., '98.		0.26	0.0097	0.0019	0.0000	0.0608	1.83	15.4	5.2	3.06	2.32	1.18	0.042

TABLE No. 12 B.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM GATE CHAMBER.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0260	0.0020	0.0001	0.1481	1.12	15.0	6.0	4.39	4.71	1.07	0.185
"	August	0.45	0.0222	0.0015	0.0000	0.0763	1.63	14.1	4.3	5.44	5.13	1.10	0.177
"	September	0.32	0.0128	0.0017	0.0000	0.0471	2.47	13.3	——	5.75	4.95	1.86	0.044
1897	October	0.26	0.0141	0.0018	0.0000	0.0670	3.41	17.2	——	5.30	4.92	2.47	0.052
"	November	0.29	0.0148	0.0017	0.0000	0.0557	3.13	21.3	3.6	4.15	3.73	2.48	0.114
"	December	0.30	0.0085	0.0014	0.0000	0.1012	1.73	15.8	3.5	1.84	1.44	1.63	0.125
1898	January	0.26	0.0070	0.0012	0.0000	0.0915	1.37	14.4	4.6	2.11	1.60	1.37	0.118
"	February	0.24	0.0106	0.0014	0.0000	0.1400	1.29	12.7	2.4	2.80	1.86	1.15	0.116
"	March	0.23	0.0102	0.0030	0.0000	0.0495	1.18	22.2	12.0	2.88	1.91	1.66	0.064
1898	April	0.23	0.0083	0.0021	0.0000	0.0544	1.29	9.0	0.1	2.75	2.11	1.14	0.040
"	May	0.29	0.0116	0.0011	0.0000	0.0300	1.39	11.0	2.7	2.79	2.19	0.74	0.042
"	June	0.25	0.0089	0.0022	0.0000	0.0394	2.16	17.8	7.7	3.34	3.15	1.13	0.013
1898	July	0.26	0.0098	0.0028	0.0000	0.0694	2.44	12.7	0.9	4.56	3.47	1.36	0.022
"	August	0.29	0.0107	0.0025	0.0000	0.0450	2.35	19.7	8.6	4.03	3.16	1.01	0.016
Average, excluding July, '97		0.28	0.0115	0.0019	0.0000	0.0667	1.99	15.5	4.6	3.67	3.05	1.47	0.073

TABLE No. 12 C.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SETTLING BASIN.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hard-Less.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Sus-pended.				
1897	July	——	0.0234	0.0031	0.0000	0.1075	1.70	14.0	5.5	4.73	6.05	1.44	0.147
"	August	0.45	0.0204	0.0015	0.0000	0.0675	1.65	11.4	1.3	5.71	5.12	1.10	0.088
"	September	0.32	0.0131	0.0019	0.0000	0.0408	2.63	13.9	——	5.47	4.91	1.84	0.041
1897	October	0.24	0.0133	0.0017	0.0000	0.0703	3.26	17.0	——	5.13	4.86	2.36	0.048
"	November	0.26	0.0147	0.0021	0.0000	0.0600	3.58	20.4	2.2	4.42	4.02	2.16	0.119
"	December	0.29	0.0089	0.0014	0.0000	0.0806	1.84	11.9	0.4	2.31	1.89	1.26	0.102
1898	January	0.22	0.0061	0.0014	0.0000	0.1069	1.47	12.0	1.7	2.06	1.67	1.51	0.126
"	February	0.24	0.0101	0.0017	0.0000	0.1500	1.38	11.1	0.3	2.94	1.91	1.14	0.088
"	March	0.22	0.0085	0.0014	0.0000	0.0450	1.24	10.4	0.4	2.81	1.87	1.00	0.038
1898	April	0.20	0.0084	0.0026	0.0000	0.0431	1.45	9.1	0.1	2.69	2.07	1.25	0.045
"	May	0.27	0.0088	0.0012	0.0000	0.0255	1.30	9.3	1.2	2.58	2.18	0.79	0.040
"	June	0.23	0.0083	0.0020	0.0000	0.0300	2.12	12.2	2.3	3.27	2.96	0.95	0.014
1898	July	0.24	0.0095	0.0026	0.0000	0.0637	2.67	14.6	2.2	4.61	3.30	1.55	0.021
"	August	0.29	0.0104	0.0024	0.0000	0.0495	2.45	16.7	5.4	3.97	3.08	1.02	0.015
Average, excluding July, '97		0.27	0.0105	0.0018	0.0000	0.0641	2.08	13.1	1.6	3.69	3.07	1.38	0.060

TABLE No. 12 D.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER No. 1.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0184	0.0051	0.0001	0.1243	2.02	28.9	1.2	6.59	9.12	1.26	0.127
"	August	0.35	0.0100	0.0009	0.0001	0.0707	1.51	10.3	——	7.30	7.16	1.07	0.034
"	September	0.06	0.0076	0.0014	0.0000	0.0548	2.43	13.8	——	6.52	6.07	1.91	0.006
1897	October	0.00	0.0078	0.0017	0.0000	0.0816	3.12	17.4	——	5.99	5.60	2.52	0.006
"	November	0.10	0.0097	0.0014	0.0000	0.0771	3.62	18.5	0.0	5.01	4.74	2.23	0.024
"	December	0.02	0.0056	0.0015	0.0000	0.0937	1.90	11.7	0.0	3.26	2.81	1.36	0.031
1898	January	0.12	0.0049	0.0011	0.0000	0.1020	1.39	9.9	0.0	3.13	2.63	1.52	0.028
"	February	0.10	0.0077	0.0013	0.0000	0.1625	1.44	10.9	0.0	3.23	2.68	1.22	0.028
"	March	0.00	0.0040	0.0016	0.0000	0.0525	1.23	9.5	0.0	3.59	2.74	1.05	0.016
1898	April	0.02	0.0050	0.0021	0.0000	0.0469	1.56	8.7	0.0	3.46	2.88	1.14	0.010
"	May	0.09	0.0048	0.0010	0.0000	0.0270	1.31	8.3	0.0	4.12	3.30	0.86	0.012
"	June	0.06	0.0057	0.0016	0.0000	0.0412	2.14	11.2	0.0	4.42	4.10	1.01	0.004
1898	July	0.09	0.0055	0.0023	0.0000	0.0731	2.60	14.2	0.0	5.97	4.67	1.66	0.005
"	August	0.12	0.0050	0.0022	0.0000	0.0465	2.56	12.5	0.0	5.36	4.37	1.12	0.004
Average, excluding July, '97		0.09	0.0064	0.0015	0.0000	0.0715	2.06	1.21	0 0	4.72	4.13	1.44	0.016

TABLE No. 12 E.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER No. 2.

(Parts per 100,000)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897	July	——	0.0158	0.0059	0.0001	0.1158	1.90	23.9	4.4	7.25	22.15	1.99	0.130
"	August	0.35	0.0101	0.0009	0.0000	0.0760	1.58	10.5	——	7.35	7.20	1.17	0.036
"	September	0.06	0.0078	0.0015	0.0000	0.0533	2.40	13.8	——	6.63	6.07	2.01	0.004
1897	October	0.00	0.0082	0.0015	0.0000	0.0722	3.17	17.9	——	6.12	5.74	2.55	0.005
"	November	0.09	0.0091	0.0015	0.0000	0.0761	3.35	18.4	0.0	5.68	5.33	2.27	0.023
"	December	0.04	0.0064	0.0012	0.0000	0.0731	1.89	11.5	0.0	3.21	2.76	1.29	0.029
1898	January	0.11	0.0046	0.0012	0.0000	0.1050	1.42	10.7	0.0	3.47	2.84	1.48	0.025
"	February	0.08	0.0073	0.0014	0.0000	0.1000	1.41	11.0	0.0	3.50	2.77	1.22	0.041
"	March	0.02	0.0039	0.0017	0.0000	0.0550	1.24	9.4	0.0	3.81	3.07	1.04	0.026
1898	April	0.02	0.0046	0.0021	0.0000	0.0469	1.42	8.6	0.0	3.62	3.02	1.14	0.012
"	May	0.10	0.0046	0.0011	0.0000	0.0255	1.25	8.2	0.0	3.81	3.32	0.74	0.011
"	June	0.05	0.0060	0.0014	0.0000	0.0319	2.16	11.4	0.0	4.58	4.30	1.04	0.003
1898	July	0.06	0.0057	0.0024	0.0000	0.0769	2.37	13.5	0.0	5.77	4.39	1.54	0.004
"	August	0.15	0.0049	0.0025	0.0000	0.0480	2.56	12.1	0.0	5.24	4.04	1.30	0.004
Average, excluding July, '97		0.09	0.0064	0.0016	0.0000	0.0646	2.02	12.1	0.0	4.83	4.22	1.45	0.017

TABLE No. 12 F.

AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM MECHANICAL FILTERS.

(Parts per 100,000.)

Year.	Month.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
						Warren Filter.							
1898	February	0.04	0.0055	0.0020	0.0000	0.0875	1.34	7.7	0.0	2.04	1.23	1.53	0.009
"	March	0.00	0.0039	0.0015	0.0000	0.0487	1.29	7.8	0.0	1.94	1.15	2.00	0.007
"	April	0.01	0.0041	0.0016	0.0000	0.0467	1.19	7.9	0.0	1.86	1.31	1.47	0.005
1898	May	0.05	0.0052	0.0014	0.0000	0.0285	1.38	8.2	0.0	2.66	1.48	1.44	0.014
"	June	0.06	0.0049	0.0015	0.0000	0.0319	2.11	10.2	0.0	4.06	2.10	1.93	0.003
1898	July	0.00	0.0045	0.0018	0.0000	0.0700	2.32	11.5	0.0	3.83	2.42	2.02	0.002
"	August	0.05	0.0051	0.0032	0.0000	0.0450	2.34	11.7	0.6	4.02	1.65	2.19	0.002
Average		0.03	0.0047	0.0019	0.0000	0.0512	1.71	9.3	0.1	2.92	1.62	1.80	0.006
						Jewell Filter.							
1898	February	0.08	0.0038	0.0017	0.0000	0.0862	1.31	7.8	0.0	2.27	1.41	1.38	0.010
"	March	0.00	0.0035	0.0015	0.0000	0.0534	1.17	7.3	0.0	2.09	1.21	1.59	0.006
"	April	0.00	0.0042	0.0018	0.0000	0.0475	1.22	7.8	0.0	1.93	1.44	1.21	0.008
1898	May	0.01	0.0040	0.0013	0.0000	0.0214	1.36	8.1	0.0	2.62	1.49	1.42	0.004
"	June	0.05	0.0050	0.0021	0.0000	0.0319	2.03	10.4	0.0	3.83	1.91	2.11	0.003
1898	July	0.05	0.0047	0.0017	0.0000	0.0600	2.40	13.6	0.0	4.57	2.48	2.23	0.003
"	August	0.04	0.0058	0.0027	0.0000	0.0435	2.45	11.6	0.5	3.87	2.10	1.72	0.002
Average		0.03	0.0044	0.0018	0.0000	0.0491	1.71	9.5	0.1	3.03	1.72	1.67	0.005

ARBITRATION.—ITS PLACE IN OUR PROFESSIONAL PRACTICE.

By G. Alexander Wright, Member, Technical Society of the Pacific Coast.

[Read before the Technical Society of the Pacific Coast, Nov. 2, 1900.*]

I do not expect to be able to present for your consideration this evening anything that can be justly termed new or original. My paper consists largely of notes made from time to time for my own guidance, with an occasional suggestion based upon experience with technical arbitrations. I will say frankly that I believe the arbitration of disputes connected with their professional work is, and should be, closely allied to the legitimate modern practice of the architect and of the engineer.

If my attempt to throw some light upon this important subject results in an interchange of thought between us, the object of my paper will have been accomplished.

The word arbitration comes to us from the Latin "Arbitratus" (to be a hearer) and "Ar" and "betere" (to go hence; one who goes to look on). This method of determining differences between men has been practiced from earliest times, and distinct references to its principles are found in the Scriptures. The Amphictyonic Council, organized 600 B. C. for the protection of the temple of the Delphi and for the abolition of war, also proposed the accomplishment of its object by arbitration very much as we know it to-day. So well recognized were these principles in Greece that when Sparta and Argos made a treaty of alliance they provided for settlement of their disputes by arbitration (as we are told) according to the custom of their "ancestors." Rome, in the pride of her glory and power, acknowledged the good side of arbitration when Pompey directed the Parthians and Armenians to regulate their differences by this means. It is interesting for us to observe also that the arbitration proceedings of to-day differ but very little from those of the ancient Greeks. In their day it was usual to make agreements, designating the arbitrator, and also the matters in dispute. It was the arbitrator who fixed the time and place of the investigation, and he was solemnly pledged to honestly discharge his trust. The "sentence" was also written out and deposited in temples or other public places, and oaths were taken by the parties that they would execute the sentence imposed.

*Manuscript received November 12, 1900.—Secretary, Ass'n of Eng. Socs.

During the Middle Ages arbitrations seem to have been more frequent, yet their beneficial influence was restrained owing to the absence among the people of the idea of conciliation. Happily, in modern times arbitration is more universally appreciated as a means of settling differences of every kind, from those of international importance to the adjustment of those manifold questions which continually affect capital and labor. So general, indeed, is this principle that in some States even breaches of contract, trespass, assaults, charges of slander, differences of partners and even breach of promise may be settled by arbitration; and so the principle has come down to us in an almost unbroken line from ancient times.

Referring for a moment to international arbitration, it is but a short time since the Emperor of Russia advocated a national conference with the object of substituting its principles among nations as a remedy for war. It should be a matter of considerable pride to us as American citizens to recall the fact that, since her birth as a nation, the United States has ever been foremost in consenting to the arbitration of questions which other nations might have considered a justification for bloodshed, and we find no fewer than forty-seven such cases in a little over one hundred years,—an excellent showing indeed. And, in addition to arbitrating her own differences, the United States has herself acted as arbitrator between other nations on some fourteen different occasions.

But, to return, there are probably no professions in which the spread of this principle has, during recent years, been greater than in connection with our contract methods of carrying out work, and we as architects or engineers may at any time be called upon to apply the recognized principles of the practice of arbitration. Our professional literature, however, seems to be somewhat silent on this useful subject. There are legal works for the attorney, of course, containing the law in the premises, the code and digests of many cases that have been heard arising out of "arbitration" proceedings, the most frequent examples being the efforts of parties wishing to set aside awards; but there is very little published adapted to the needs of the layman who finds himself, for the first time, occupying the position of arbitrator.

Let us therefore briefly consider the subject to-night as practical laymen rather than from the legal standpoint.

In the trial of technical suits there has never been a time when the best technical testimony has been more sought after than now, and the reason for this is not far to seek. Indeed, the time is not far distant, I think, when the courts will realize the advantage of referring such technical cases entirely to the professional expert.

This method is quite prevalent in older countries, and it is of immense advantage to litigants, while at the same time it greatly facilitates the work of the courts. Who is there among us who does not recall some technical case which ought to have been determined by arbitration rather than by a suit? Is it not safe to say it would have been settled more quickly, more economically and perhaps more satisfactorily to the parties concerned?

Arbitration, as regulated by statute, certainly results in prompt and equitable settlements, and without causing that bitterness of feeling between the parties which sometimes results in enforcing their claims in our courts of law. It is a practical remedy for long-continued technical suits, and can be applied by practical men who certainly have the advantage of understanding the technical points involved. In short, it may be called the substitution of reason for force.

Take an ordinary case, one that might arise any day in our practice. A client, for example, declines to pay for extra work; by no means an uncommon incident. In such a case arbitration may arise by the terms of the contract or by subsequent consent of the parties. Either of these methods is better for the disputants than a suit, because no expense or loss of time is incurred in preparing and waiting for trial. This is no small advantage in itself.

The first step is for the disputing parties to enter into an agreement whereby they consent not only to arbitrate their differences, but to abide by the award. This agreement is technically known as the submission, and the subsequent award depends largely upon its terms and conditions. Its preparation requires some care, and this is often attended to by the attorney of one of the parties and submitted for the approval of the attorney on the other side. But there is no reason why it cannot be prepared by an engineer or an architect, the same as he may prepare his award, or a contract, or specification or any other document required in his regular practice, provided the submission be in accordance with Section 1283, Code of Civil Procedure. Assuming, however, that the submission is best prepared by the attorney of one side, I have found it no disadvantage for the arbitrators to be acquainted with the fundamental principles involved, and it is these only with which we are now dealing. But the essential point involved in this question of arbitration is not so much in the technical knowledge necessary to prepare a submission as it is to so present the facts to disputing clients and others that they shall prefer arbitration in place of resisting technical claims in the courts. Indeed, I do not think professional ethics would be violated if at every suitable opportunity

we were to give prominence to the advantages of arbitration over actions at law in matters of technical dispute.

The submission must be in writing, and, if proceeding under the provisions of the Code of Civil Procedure, it may be entered as an order of the Superior Court. This is done by filing the document with the clerk of the county in which one of the parties resides. In San Francisco the filing fee is $6.00. A note of the filing of the submission must thereupon be entered by the county clerk in the Register of Actions, as held in the case of Kettleman *vs.* Treadway, 65 Cal. 505. The mere authority to file, without the act, is insufficient, but by inspecting the Register of Actions an arbitrator may always satisfy himself that this has been done. The entry should contain the necessary particulars,—for example, the names of the arbitrators and the time limited by the submission (if any) within which the award must be made. After such entry has been made a submission cannot be revoked without the consent of both parties. But in the case of the California Academy of Sciences *vs.* Fletcher, 99 Cal. 207, it would appear that the word "thereupon" does not necessarily mean "immediately," for in this case such entry was not completely made until nineteen days after the award was made and filed; but it was held that jurisdiction did exist to enter judgment upon the award, which was done. We see, therefore, that the submission may be filed at any time before judgment is entered upon the award.

In a general way any person legally capable of making a contract may submit controversies to arbitration, but it must be remembered that a single partner cannot bind his co-partners to arbitration unless his co-partners have wholly abandoned the business to him, or are incapable of acting (Sec. 2430, C. C. P.). The case of Jones *vs.* Bailey, 5 Cal. 345, has a good decision on this point.

Arbitrators should allow a reasonable time when fixing a date of hearing, in order that both sides may be ready to present their respective claims and testimony.

Should either side wish to be represented by counsel before the Board of Arbitration, it would be proper to notify the other side of such intention; and, although arbitrators are not bound to hear counsel, it would scarcely seem to be right to refuse to do so. In such cases especially the attendance of a stenographer is desirable to take verbatim notes of the proceedings.

Although not compulsory, I have found it a good plan to have a schedule of the specific matters in difference made part of the submission. This prevents the possible importation of other matters by the parties during the hearing, a practice which, if permitted, always causes unnecessary discussion and loss of time.

A disputant may nominate any person as his arbitrator, for every person has the right to select whom he pleases for his private judge; but in seeking to take the benefit of his right to arbitration he should use discretion and judgment, such as might be displayed, for example, in the selection of a juryman.

In matters of accounts mercantile men are often selected; in other cases attorneys; in others architects or engineers, and so forth, according to the nature of the subject-matter in dispute. An arbitrator's chief qualifications are good judgment, impartiality, clear-headedness and patience. He should be absolutely free from bias or feeling in act and expression. If he is unfriendly in the slightest degree toward the party on the opposite side, it would be better for him not to act. Should the parties happen to be either his creditors or debtors, that alone need not prevent his acting. He should not accept any favors, nor even any part of his legitimate fees prior to the award. Such acts are liable to misconstruction, although done in the best of good faith. Disputants should beware of nominating as arbitrator persons known to be prejudiced in their favor, or whose minds are already made up regarding any of the matters in difference. No honest arbitrator would act under such conditions. Indeed, in such a case the subsequent proceedings would become a farce instead of a benefit.

Above all, his mind should at all times be open to honest conviction, any disposition to stubbornness or laxity being carefully avoided. In short, much depends upon the judgment and broad-mindedness of an arbitrator.

Having been appointed and named in the submission signed by both parties, the arbitrator's first duty is to qualify before an officer authorized to administer oaths, by declaring that he will faithfully and fairly hear the allegations and evidence and make a just and true award according to his understanding; and the umpire, when appointed by the arbitrators, will also make similar oath.

Regarding the "powers" of arbitrators, they occupy a similar position to those of judges of the Superior Court, the principal exception being that they are without contempt powers. They should endeavor as far as possible to arrive at correct conclusions by the same rules as would have governed the court for which they have, for the time being, been substituted. The exact terms of the submission must be closely followed, and its specific language complied with. Arbitrators, however, are neither expected nor compelled to follow court methods exactly. Indeed, if the award is an equitable decision, made in good faith, the actual law in the

case may be disregarded, and the award would not necessarily be thereby rendered invalid and void; but, if it can be shown that the arbitrators intended to decide according to law and that they were in error, then the court might set aside the award.

It is the arbitrators' duty to appoint a time and place of hearing; to notify the parties thereof; to adjourn as often as necessary; to administer the oath, and, above all, they must act "together," and *not* individually, in all things. The majority may determine any question. In other words, two may do any legal act authorized by the terms of the submission that three may do. They must decide on *all* the controversies submitted, omitting to consider nothing and leaving nothing in doubt or undecided. They must, of course, hear evidence on both sides. Lord Eldon, the eminent jurist, once said, "By the great principles of eternal justice (which is before all acts, regulations and proceedings of court), it is impossible that an award can stand where arbitrators hear one side and decline to hear the other." I think the case of Curtiss *vs.* City of Sacramento, 62 Cal. 102, presents an interesting point. It is an application to set aside an award on the ground that no opportunity was given the parties to submit evidence, and, briefly, the point arose in this way: Two arbitrators met, without a third, and took testimony; the third one arrived at a decision by reading over the notes of the evidence without being present when it was given. It was held that the award was invalid and void.

The duties of the arbitrator must not be delegated to another. If, however, the opinion or knowledge of any person (for example, an independent attorney) is necessary to "confirm" the understanding of an arbitrator, it is allowable to obtain such assistance, but the greatest possible care must be taken not to blindly follow such person's opinion or knowledge. Again, in the same way, it is customary for an arbitrator, when necessary, to consult with outside parties regarding, for example, matters of construction or prices, but it must be for the purpose only of fortifying his own opinion. This also should be done with caution, for, as a matter of principle, it is dangerous to go outside for evidence, and perhaps it is safer, after all, to obtain opinions by placing such parties upon the witness stand in the regular way.

Each arbitrator should carefully study every detail of his case, however small, bearing in mind "precedents," trade customs, etc., if any exist, and leaving nothing to chance. Still, arbitrators must remember that they are judges, not advocates, of the parties. I have met inexperienced arbitrators whose sole idea of their duty seemed to be to advocate for and to take everything in sight,

regardless of equity and justice. But this is not arbitration. It is a direct violation of the arbitrator's oath to hear fairly the allegations and to make a just and true award according to his understanding.

In some "submissions" I have seen a clause to the effect that the parties agree not to appeal from the award, but this does not of course prevent the court from exercising its jurisdiction if occasion demands.

My knowledge of the statutes is insufficient to warrant my saying that the Legislature intended an arbitrator's award to be absolutely final and beyond appeal (except, of course, for fraud), but I think such was the original intention, and I would certainly be in favor of an amendment making it so.

Now let us consider the matter of the third party, or umpire. Provision is made in the arbitration clause of many contracts that if the two arbitrators cannot agree they shall then select a third to act with them. It has been held in Dudley *vs.* Thomas, 23 Cal. 365, that arbitrators duly qualified may appoint the umpire at *any time,* and it would therefore appear that it is quite unnecessary to defer the appointment of umpire until disagreement between the two arbitrators occurs, although this may be so stipulated in a contract agreement. At any rate, it is found to be a bad and inconvenient condition in actual arbitration practice, and it is better and proper, in my opinion, for the umpire to be selected immediately after the arbitrators and before the investigation is commenced. A convenient arrangement is for him to act as chairman of the commission. By so doing he has the opportunity not only of hearing, but of directing the presentation of testimony from the commencement of the proceedings; and he is thus enabled to render his decisions without putting witnesses on the stand twice over, which would otherwise be necessary if the two original arbitrators were unable to agree.

The umpire should refrain from voluntarily joining in any discussion between the arbitrators in their efforts to agree, his duty being to decide if they cannot agree. Arbitrators should not permit parties to a submission to influence them in the nomination of persons to act as umpire. The selection lies with the arbitrators alone, and it makes no difference whether the parties are satisfied with such selection.

It may be also well to remember that an umpire must be "selected," and his appointment should be in writing by agreement between the arbitrators. But he should not be chosen by drawing lots or by the tossing up of a coin, a method which I have known to

be suggested when the names of two or more equally eligible parties have been named for umpire. A case sometimes occurs in which arbitrators, although acting in perfectly good faith, are unable to agree upon a third party, and I am unaware of any power of the courts to compel arbitrators to agree on an umpire. Not so long ago I had a case of this kind in my own practice. The conditions were such that it was impossible to agree upon an umpire. My co-arbitrator was inexperienced and stubborn. The arbitration was abandoned. Suit followed, and in due course judgment was rendered in favor of my co-arbitrator's side, but for about one-third of the amount which, I feel sure, would have been awarded by arbitration. This is a good illustration of the effect of stubbornness on the part of an arbitrator.

Touching upon the subject of evidence, all witnesses must of course be sworn. Plans, specifications, correspondence, etc., should always be identified by testimony and numbered as exhibits before being admitted as evidence. Memoranda made in books by one of the disputants stand in very much the same light as heresay evidence, and should be accepted with reserve, for nothing can prevent any one from making entries exactly to suit his case. Such entries may be used, however, by the opposite party if so desired.

A jury is very apt to attach undue importance to a large number of witnesses, but a few good men of known reputation are more convincing to technical arbitrators, for they have the necessary skill and judgment to be able to decide for themselves just what portion of such evidence they may justly accept or reject. This, I think, is a strong argument; not only in favor of arbitration itself, but in favor of technical arbitration occupying its proper place as a branch of our professional work.

A few words about the award. When all the testimony is in and the controversies are decided, the arbitrators prepare their award, usually in writing, although a verbal award, in other respects good, would not be invalid.

It is usual to recite from the submission the authority for the investigation, and other points essential to clearness. The award should preferably be written by the arbitrators, or one of them, and not, for example, by the attorney of one of the parties. It must be definite, unmistakable and conclusive in its language. The expression sometimes used by arbitrators, "We *propose* that such a thing should be done," is ambiguous, and should not be employed. "We *direct*" is much to be preferred.

The award must not only state the amount of money due from one party to the other, but it should direct its payment and when it

is to be paid, otherwise non-payment would not constitute a disobedience of the award. It should conform to the terms of the submission, and deal only with the specific matters of controversy, and nothing more nor less. It should state, moreover, that all the evidence has been heard, and that all disputed matters have been determined and closed; otherwise the award is liable to be held defective and to be set aside. The greatest care is necessary in writing out the award, for it cannot be legally altered by the arbitrators even to correct errors. Any corrections so made will be void, and the language originally written will stand good. The court may, however, on motion, correct or modify an award upon a proper showing, as, for example, in the case of a miscalculation of figures.

Arbitrators are not required to give details of their figures, nor reasons, nor explanations for arriving at their conclusions any more than judges of the court are required to do such things. Comments or discussions thereon with the parties or their acquaintances are best avoided.

If the submission has been filed with the county clerk, the award must also be filed and a note thereof made in the Register of Actions, in order that the award may be entered as a judgment or order of the court.

An award may be set aside if serious irregularities can be shown,—for example, corruption, fraud, gross error or material irregularity; refusing to postpone a hearing, or acting in such a way that the rights of the parties were prejudiced. But an award cannot be impeached solely as being contrary to law and evidence (see Carsley *vs.* Lindsay, 14 Cal. 394). This is a good point to bear in mind. I remember a recent case in which one of three arbitrators declined to sign the award, upon the ground that it was contrary to the evidence, and he filed a minority report to this effect. But it will be seen that this proceeding would have been of little or no value in any attempt to impeach the award. As a general thing I think it is better *not* to make a "minority" report, notwithstanding an arbitrator may not be able to conscientiously agree to the award. Where it is possible to do so, it is better for all the arbitrators to unite and sign the award. I believe that even an attempt to set aside an award on the ground of refusing to hear certain evidence has been overruled, but I am unable for the moment to cite the case.

The reason for the foregoing seeming strictness exhibited by the courts in reference to arbitrations is because arbitration is a purely statutory proceeding, and there can be no doubt whatever that the statute must be closely followed.

Having touched upon the fundamental principles regulating arbitration, let us proceed to consider its advantages, especially in regard to those technical disputes which come under our observation as engineers and architects.

A court trial differs of course from one held before technical judges. In the former witnesses are always entitled to be considered as truthful until proved to be otherwise. The court knows nothing personally of the "weight" which might reasonably be attached to their technical testimony beyond what appears on the face of the evidence; whereas technical or trade witnesses testifying before a technical tribunal would, in all probability, be personally known by one or more of them, and their reputations could be considered; and, such arbitrators being personally familiar with the subject-matter of such testimony, could make allowances, and estimate such evidence at its proper value.

Again, expert and also trade testimony in court have been known to differ considerably, but technical arbitrators would, of their own experience, understand such matters and be able to discover reasons for such differences or errors and, as I have stated, to make due allowances therefor.

Another advantage is that the hour and place of hearing may in some measure be fixed to suit the convenience of the parties and their witnesses. This concession cannot of course be obtained, nor expected, from the courts.

Sometimes it happens that neither the court nor disputants' attorneys are sufficiently acquainted with the true interpretation of drawings, details, specifications, etc., nor, indeed, with much of the technique appertaining to our professional work, nor can it be expected that they should be. And so it happens that we sometimes hear of the details of technical cases being insufficiently understood by both court and counsel during a trial. And although a verdict under such conditions may be a just one, as far as the *law* is concerned, it may not be "equity," viewed in the customary technical light of practical minds.

Then, as regards quick settlement of technical cases and costs, I submit that the best results are usually obtained by early arbitration, when all the matters are still fresh in the minds of all parties and of their witnesses. Indeed, this very point has recently been brought forcibly to my attention, for during the time in which I was engaged in preparing this paper I was subpœnaed to give testimony in a suit regarding the quantity of certain work done in a building not far from here, and I found that the dispute had extended over three years, although the amount of the claim was

only about four hundred dollars. But if the matter had been arbitrated three years ago a saving of time and money would have been effected, and probably without producing strained relations on either side.

Then, again, in arbitration there is more opportunity and latitude for producing rebuttal evidence, but in court, if the best and strongest testimony be not produced according to the rules of the court, the opportunity of doing so may be lost. Again, there is less risk of one side being overthrown by "surprise" testimony, as occurs sometimes in court. Technical arbitrators have a way of getting down into the facts. They go at once to the very essence of the dispute, and are hampered neither by court rules nor by precedent. In short, they get at the facts, and are able to render judgment accordingly in a common-sense, practical manner.

It is only right perhaps that I should refer to one or two of the objections which one occasionally hears against arbitration. I have heard it alleged that arbitrators may be uncertain judges, admitting evidence of a certain nature at one time and rejecting it at another. It is sometimes said that arbitrators are liable to be inconsistent regarding the weight of evidence submitted, or that they may be very firm and hard to convince to-day and unnecessarily yielding to-morrow, and so on. But these objections do not hold good, I think, where arbitrators have had the advantage of experience. I have heard it stated that arbitration is good provided there are perfect arbitrators, but would it not be equally reasonable and convincing to say that the courts are good provided every judge is perfect? And it is doubtful whether his honor himself could maintain that this condition has always existed, though it is very far from my intention to suggest the least disrespect to the honorable and painstaking judges of our courts.

It of course happens sometimes that both parties to an arbitration are no more satisfied with an award than others may be with a court decision. This often arises from a misunderstanding or lack of knowledge as to the real objects of arbitration. Occasionally one meets those who cherish a grievance unless they are awarded the whole, or nearly so, of whatever they choose to claim. But such cases are very rare, and they in no way affect the great principle,—viz, the undoubted advantage of the application of arbitration to technical disputes. As a general rule I find fair-minded and reasonable persons are not only satisfied with awards, but heartily glad to get their differences so quickly adjusted and off their minds without resorting to an action at law. While it is true that some contract agreements provide for arbitration of disputes

between the actual parties to such contract, this provision does not of course provide for settlement of any disputes that may arise between other parties, and which do arise; and we have but to refer to the court calendar to see how frequently such technical cases are taken into court.

Having now touched briefly upon the fundamental principles of arbitration, I may be excused perhaps for presenting for your consideration one or two thoughts that have occurred to me in regard to the settlement of those differences which affect the engineer and architect, the contractor and the client.

First. Arbitration is perhaps one of the most practical of subjects in the statutes. A practical man can understand and readily apply its fundamental principles; a further knowledge of which might well form a part of our professional training, enabling us to occupy with better advantage the position of technical arbitrator when the necessities of our practice require it.

Second. I would even favor compulsory arbitration of all technical or trade disputes, believing that the interests of all can best be served by its adoption. Take, for example, the differences which will sometimes arise between the professional man and his client. Most of us know something of the uncertainty of submitting such differences in court to a jury of laymen. Such matters should, I think, be invariably adjusted by technical men who are familiar with what is right and proper in such cases.

Third. It would seem to me to be an important advantage to technical disputants and a relief to the court calendar and practice if a permanent technical court or tribunal could be established, where all cases, such as occur in the work of the engineer and architect, might be referred and be quickly determined beyond appeal by technical men along arbitration lines; or, if this should be considered too sweeping a change in our judiciary methods, then perhaps a particular judge might be set apart and be given a special court to try (in conjunction with technical advisers who would sit in bank with him) the particular classes of cases under consideration. These, gentlemen, are merely suggestions which I offer as being possible remedies for existing conditions, and which are known to be capable of improvement by those of us who have had experience with technical trials in courts of law.

In conclusion, I hope I have not detained you too long. If my enthusiasm has led me into saying too much, it is because I believe in my subject, believe in its equity and believe it to be the quickest and most inexpensive process for settling those vexatious technical disputes which sometimes arise. These are also my reasons for believing that arbitration has its place in our modern professional practice.

A SUCCESSFUL SIPHON.

By Robert S. Hale, Member Boston Society of Civil Engineers.

[Read before the Society, October 17, 1900.*]

The following paper describes the solution of a problem occurring in a small water-supply plant. The problem has been solved satisfactorily by the use of an air-tight siphon at a cost of about $250, as against a cost of several thousand dollars which would have been incurred if the pipe had been laid to grade, or as against less efficient service together with an annual cost of nearly $100 if an air chamber had been provided and kept free of air by a pump. While the solution is simple, it was not referred to in the text-books or reference books which I consulted, nor was it thought practicable by a number of engineers with whom I talked the matter over. A description may therefore prove of interest.

The Bee Hive Mountain Aqueduct Company is a private company supplying seven houses and four barns at Schooner Head, Bar Harbor, Maine. The works supply also a private golf course and a number of lawns, requiring a good deal of water for sprinkling. The supply is taken from a small pond at about 400 feet above sea level. Close to the pond is a ridge about 200 feet wide, rising to 12 feet above the level of the pond, through or over which the water must be carried to the houses. These are from 20 to 100 feet above sea level, or an average of about 350 feet below the level of the pond.

The houses are inhabited only during warm weather, and this fact obviated any necessity of burying the pipes. The first installation consisted of a 2-inch galvanized iron pipe, with screw joints, laid over the ridge. This siphoned the water over the ridge and would work satisfactorily for a few hours, after which time the siphon would break. Two or three of the plumbers at Bar Harbor, including the one who laid the first pipe, took turns in taking contracts to keep the siphon in operation for the season, but the only successful method was to open a waste pipe about 200 feet below the level of the ridge. This waste pipe gave a continuous flow through the siphon, and the result was satisfactory so far as the supply of water at Schooner Head was concerned. The method, however, involved an excessive waste of water, which lowered the level of the pond to an undesirable amount and reduced the available pressure at the houses.

*Manuscript received November 24, 1900.—Secretary, Ass'n of Eng. Socs.

Among the other means which were tried to keep the siphon in operation were:

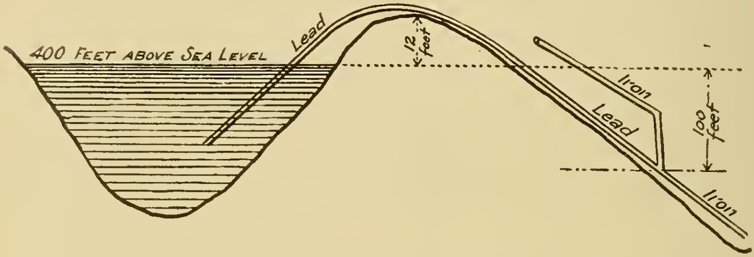
1. The use of foot valves at the pond.

2. The use of a vent on the delivery side, in order to prevent air backing up to the top of the siphon.

3. Taping the joints of the pipe with electric tape. This kept the siphon in operation eleven days, when the supply failed. The joints were retaped and the siphon restarted, after which it held three days and then failed again. After that, taping the joints seemed to have no effect.

4. Tarring the joints. This could not be well done, as the pipe could not easily be heated before applying the tar.

After the plumbing contractors of Bar Harbor had tried for several years to keep the siphon in operation without the waste of water due to the drip, the matter was referred to a committee



consisting of Mr. G. T. Francis, Mr. R. W. Hale and myself. Mr. W. L. Pierce, a contractor of Bar Harbor, was anxious to try a lead pipe for the siphon, while some of the directors of the company desired to cut through the ridge. On obtaining estimates of cost, it appeared that it would cost about $6000 to cut through the ridge (which was all rock), and about $250 to lay a 1-inch lead pipe. It also appeared, from the study of the means previously tried for keeping the siphon in operation, that the failures were due to indraft of air through the joints of the iron pipe, which would not occur if lead pipe with wiped joints were used. That the trouble was due to air leaks at the joints was indicated also by the fact that the joints all leaked when put under water pressure.

The committee, therefore, reported in favor of a lead pipe, and this was put in last spring, water being turned into it on April 9. The siphon has held continuously from that day to October 17, the date of writing, without breaking and without waste. The result is a complete success, and the level of the

pond is hardly appreciably lowered by the use of the water, instead of being lowered several feet as in former years (on account of the waste pipe). The pressure at the houses is higher than ever before, since the loss of head due to replacing 500 feet of 2-inch iron pipe with 1-inch lead pipe is less than was the loss of head due to the waste pipe formerly kept open.

The present arrangement of the pipes is as shown in the sketch.

A portion of the old 2-inch iron pipe, some 200 feet long, serves as a vent to get rid of any air carried over from the pond. See figure.

A rough estimate of the delivery of the siphon was made by placing the end of the lead pipe horizontal (by spirit level) and measuring the fall of the jet below this level in a given distance.

The computations showed a friction coefficient of 0.032 where Merriman's tables give 0.029. This agreement is closer than can be expected for such rough measurements, and it is safe to say that the pipe delivers nearly the same quantity that it would if there were no siphon.

When the lead pipe was delivering from its lower end into the air it was noticed that every few seconds a bubble of air came over from the pond. This may have been due to an air leak at some point, or to air that was given off from the water at the top of the siphon at less than atmospheric pressure, and that had not had time to redissolve. The latter is the more probable cause, since a leak would cause the siphon to break, which it has not done since it was started under the new conditions.

When considering the general question of a siphon, a short study of authorities showed me only two references. Merriman (page 192) merely says that a pump must be placed at the highest point. Kent (M. E. Handbook, page 582) describes two siphons, neither of which worked unless air was removed. When running, one gave about 25 per cent. less than the theoretical, and the other gave the same as the theoretical discharge for that size of pipe. The 25 per cent. deficiency in the first case may have been due to an unnoticed accumulation of air at some point.

No reference was found to any siphon that worked without removing the air, or to any attempt to make a siphon air-tight.

It should be noted that the Bee Hive Mountain pipe is a very small one, and that the velocity is high enough to carry small bubbles of air over the ridge and down to the vent pipe. For a large size of pipe the velocity necessary to carry air bubbles over the ridge must be higher than for a small pipe, and for a very

large pipe an air chamber might be necessary even for an air-tight pipe.

CONCLUSIONS.

First. The past and present experience of the Bee Hive Mountain Aqueduct Company indicates that the former breaking of its siphon was due to indraft of air at the joints. It is probable that this is the case with most siphons that give trouble.

Second. The use of an air-tight pipe (such as a lead pipe with wiped joints) will, for small pipes at least, make a siphon deliver permanently without the use of air pumps or chambers.

Third. The use of a vent pipe on the delivery side, as at the Bee Hive Mountain Aqueduct Company, which frees the pipe from air instead of letting the air back up into the siphon, is probably an advantage.

Fourth. While lead pipe is expensive, yet there are probably a number of cases, besides the one described, in which the use of a siphon made of air-tight pipe will be cheaper than either laying the pipe below the hydraulic gradient, or using an air chamber and pump.

OBITUARY.

William Giddings Curtis.

The Technical Society of the Pacific Coast has lost one of its prominent and active members in W. G. Curtis, late engineer of maintenance of way, Southern Pacific Company, who died at Highland Springs, California, June 15, 1900.

He became a member in the early history of the organization, and always evinced a lively interest in the affairs of the Society, having been elected for a number of terms to the Executive Council and to the Vice-Presidency, which brought him in direct contact with many of the active members, who always found in him a genial companion, an accomplished gentleman and an engineer of great experience in the particular line which he had, in every sense of the word, made his life's work, and in which he was always found ready and willing to give the benefit of his observations to his fellow engineers.

Mr. Curtis, with his manifold professional duties, always found time to do his share of the Society's work. When approached for a professional paper he usually acquiesced, and when he did so he made his subject a serious study and brought his well-digested data to the notice of our members in such shape that it became of immediate practical value.

An instance in this direction is a paper written six years ago on the subject of "Timber Preserving Methods," which found such a wide circulation that it will be necessary for the Society to have it reprinted in the immediate future.

As many as thirty copies were sent to South Africa, and only recently six were sent upon an application from an eminent consulting engineer in Cape Town.

It is with great regret that your committee performs the sad duty of embodying in a memoir a few of the salient features that now make up the history of this remarkable life, which was ended in its very prime, when, with every faculty sharpened and matured, so much more might have been accomplished which must now be our loss.

Our late member was born at Bridgeport, Connecticut, August 12, 1849. He came to California when a young lad of fifteen with his family, who settled here in 1864.

Mr. Curtis's ancestors were English. The first of the family to come to this country was William Curtis, who arrived in 1632

in the ship "Lion," from Essex county, England, and settled in Connecticut.

His engineering experience began early, and from the lowest round of the ladder, for he entered the railway service as a rodman in the engineering department in 1865.

A remarkable character like that of Mr. Curtis did not long remain unnoticed. His abilities were soon recognized, and he was promoted rapidly from position to position, until at his death he held that of engineer of maintenance of way, Pacific system and lines in Oregon, Southern Pacific Company.

The enterprises which Mr. Curtis undertook and carried to a successful completion were so varied, and many of them are so well known in connection with him by the engineers of this coast, that it would be needless to review or enumerate them.

Socially he was a general favorite. He was a man of many and varied accomplishments; of prodigious memory, affable in manner and refined in expression, so that he was respected and admired by all his associates and subordinates.

He was a fluent and graceful speaker, with finely modulated voice, elegant gestures and dignified address, who never failed to be entertaining whatever his subject might have been. As a writer he was clear and concise. He wrote numerous papers upon technical subjects, all of which are characterized by that painstaking study, close thought and logical reasoning which distinguished the man.

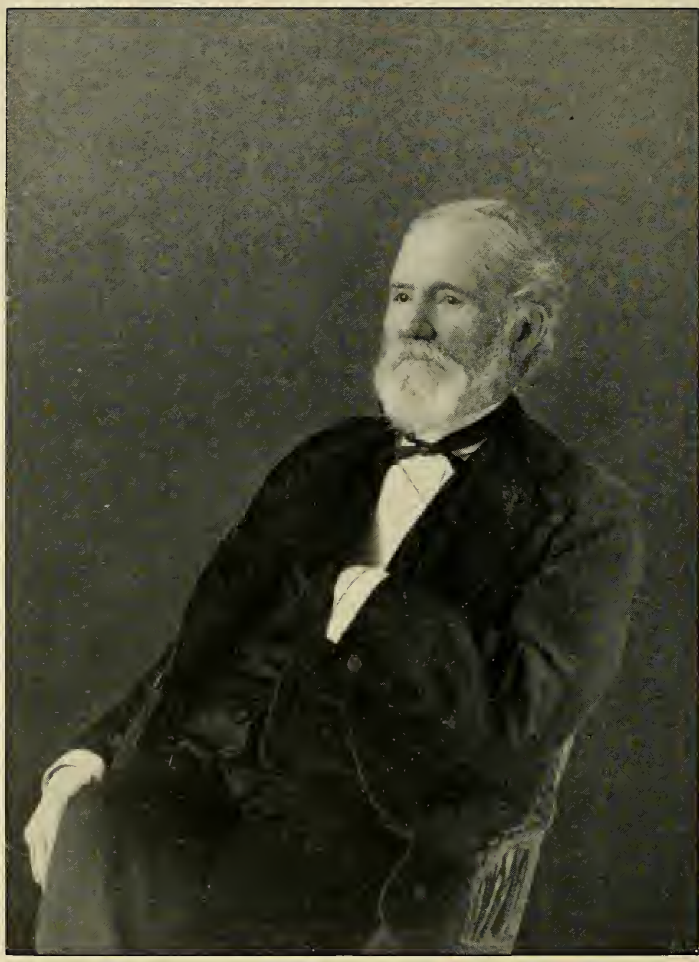
Mr. Curtis was married June 15, 1875, to Mary Elizabeth Burton, at Stockton, California, who survives him.

With these few points, taken from the life of this honorable, genial and accomplished colleague, your committee begs to offer the following resolution:

That in the death of William Giddings Curtis the Technical Society has sustained a very great loss, which all those must appreciate most keenly who have had the good fortune to come into close contact with this man.

As an engineer this loss is shared not only by the Southern Pacific Company, but by the entire technical profession, who will mourn his untimely death with us.

J. H. Wallace,
Otto von Geldern,
Committee.



JOHN H. BLAKE.

Honorary Member, Boston Society of Civil Engineers.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

STAMP MILLING OF FREE GOLD ORES.

BY DANA HARMON, MEMBER TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, September 7, 1900.*]

I WOULD not have it understood that I have reached any one given method of treatment applicable to all ores.

There are certain fundamentals to which I wish to address myself to-night. I believe that these underlying principles must be followed for all ores falling within the lines of my caption.

The local variance which must be had for ores of different localities are mainly those of screen and water, matters determinable by assaying the tailings.

MACHINERY.

Without going into the details of mill construction, it may be well to note some points bearing upon the work to be performed. Millwrights are seldom millmen.

Mortars and tables are of all shapes. Figs. 1, 2 and 3 show my own preferences.

There is such a wide difference in jar between the 850-pound and 1100-pound stamps that for the latter most substantial construction is essential.

BACK KNEE FRAME.

I prefer the back knee frame because of its solid bracing to the ore bin. The tappets are in plain sight; the pull of the belt is downward on the cam shaft; it requires less lumber. I build a flat-bottom ore bin in order to strengthen the anchorage and bracing.

The objections that such line shaft is subjected to dirt and awkward position need not lie. Set the base of the mortar 6 feet

*Manuscript received October 23, 1900.—Secretary, Ass'n of Eng. Socs.

above the ground, instead of $3\frac{1}{2}$ or 4 feet, as is customary with contractors. This will give plenty of head room around the shaft and pulleys. Tight wood boxes encasing the shaft bearings will keep out dirt. Plank or cement this mud sill floor. Whitewash every post and wall; oil cups on bearings.

In figuring on power, the uncertain factor is friction, and if bearings are to be saddled with dirt and gum, as in the dark they surely will be, power is wasted. The personal equation is an important item in connection with friction.

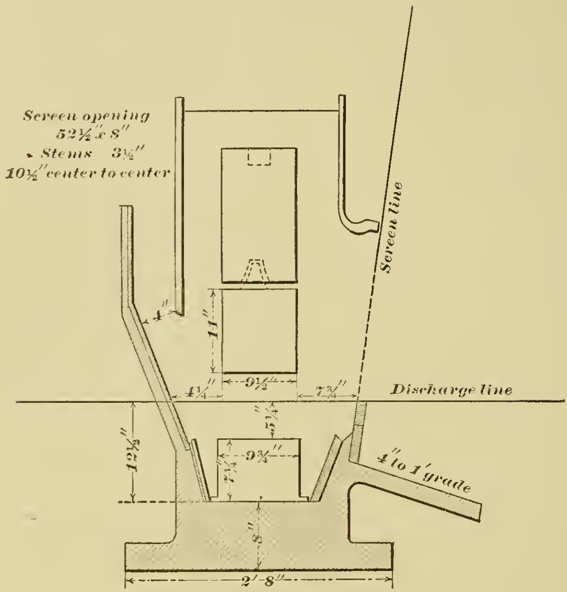


Figure 1.

Mortar, with steel shoe and iron die.

Mortar	7100 lbs.
Stem	440 "
Tappet	140 "
Boss	292 "
Shoe	244 "
Stamp	1116 "

MORTAR BLOCKS.

If wooden mortar blocks are used, make them long,—16 feet,—set on solid rock foundation, with a bedding of an inch of clean sand. Ram with concrete on sides and ends. This concrete should not be continuous all around the mortar blocks. There should be open spaces leading to the bottom of the pit; these spaces to be filled with sand, dry, or tailings run in. There is no better preservative to wooden mortar blocks than constant wetting. These sand pillars insure thorough saturation of the wood.

Excavate the pit so that you can also build up a concrete pier for the battery posts to rest on. Have anchor bolts in these piers, so that you can draw-bolt the battery posts and line sills solid to the concrete. Ordinarily the battery post is mortised into the line sill, the latter being bolted to the mud sills; but this method leaves a wide space and allows the post to spring.

The mortar blocks can be solid,—*i.e.*, two blocks bolted and keyed together,—or they can be built up of 2-inch plank nailed and bolted together. The mortar bolts are usually $1\frac{1}{2}$ x 30 inches. I think they should be longer, say 42 inches.

CONCRETE MORTAR BLOCKS.

Within the past few years concrete mortar blocks are coming into vogue. The concrete is capped with a single block of granite or iron, a sheet of lead between the mortar and this capping. Another plan has been to omit the granite or iron cap piece, and instead make the base of the mortar wider. Battery posts also are set on concrete piers.

I do not know how well these have withstood the jar of heavy mills, nor do I consider that their withstanding the jar of a 900-pound stamp is any evidence or proof of the effect an 1100-pound stamp will have upon them.

It is reasonable to expect greater crushing capacity from such rigid foundations. I should look for crystallized bolts because of this very rigidity. But I shall endeavor to show that in mortars set on wooden blocks we can crush as much as we are able to amalgamate.

It is urged against the wooden block that it will rot out in eight to twelve years; that it is well-nigh ruined if the mill stands idle a summer or two.

It has occurred to me—and I throw it out as a suggestion only—that a durable composite mortar block could be constructed, the lower half of concrete up to the ground line, the upper half (6 feet) of wood block on end; this block to be anchor-bolted to the concrete.

This would secure solidity, would escape the excessive rigidity and would permit renewal of the woodwork at reasonable expense.

GUIDES.

Use the individual iron guide—guides without the wood bushing.

The stem will not be worn by rubbing directly against the cast iron guide with one-sixteenth of an inch play on either side. Oil

sparingly, say once a fortnight, by just touching the stem with waste moistened with a good quality of machine oil.

There are iron guides with wood bushings, but I have never seen one worth buying. It would be well to have the cap-piece of malleable iron, and the bed-piece should be 2 inches thick to avoid breakage.

With the old-fashioned oak guides there is too much friction, too much wear from burning. After a few months the shoe will not center on the die.

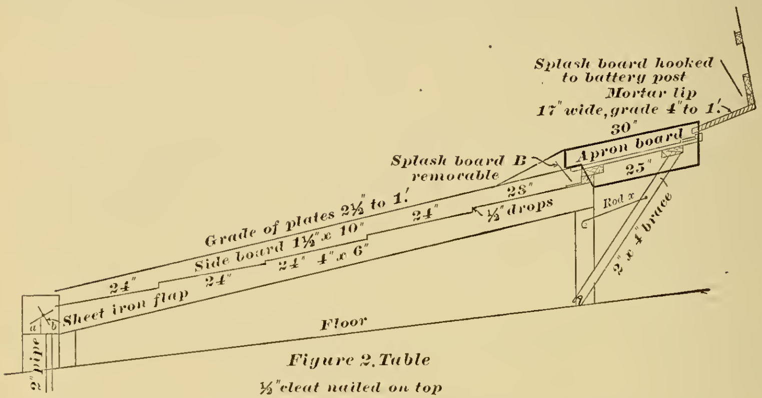


Figure 2. Table

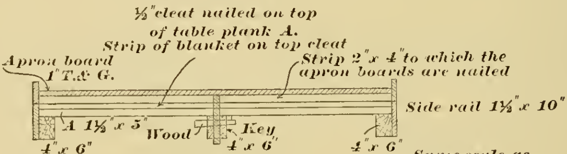


Figure 3
Table- End View

Table to be made of sugar pine, half seasoned.
4 table plank 1½″ x 24″ x 5′.
1 " " 1½″ x 28″ x 5′.
Strip of sheet iron 4″ wide under splashboard B; another 6″ wide under lip to prevent scour of plates.
The apron board 30″ x 5′ fits snug upon main table and is held ½″ away from the mortar lip by brace. The key holds it tight upon main table. Apron board removable. Unhook rods and take out braces. A 2″ x 4″ brace on each end of the apron board.

With the individual iron guide the stems will keep cool. With the oak guide the stems are always warm, and often hot. Heat means friction.

SCREENS.

I prefer the tin, costing $\frac{1}{4}$ cent per ton crushed. Neither Russia iron, brass wire nor steel can compete with this. Put strips, $\frac{3}{4}$-inch wide, of $\frac{1}{32}$-inch cheap rubber sheet packing between the tin and the wood frame, and you will at least double the life of the tin screen. Before using burn off the tin over a clear forge fire; just heat to redness, keeping the screen moving to and fro over the fire. This anneals and toughens the iron.

The three commercial sizes are: No. 0 = No. 8 needle, 441 holes to square inch. No. 1 = No. 7 needle, 324 holes to square inch. No. 2 = No. 4 needle, 225 holes to square inch.

No. 3 is too coarse for quartz.

If manufacturers would punch a size between the No. 0 and No. 1, and also a size a trifle coarser than No. 2, the range of tin screens would cover nearly all cases of quartz milling. The screen should have a selvage finish at both ends.

LINERS.

Use mortar liners, removable at every clean-up. The main back liner, instead of being in one piece, should be cut so as to give a lower piece of same width as the front liner.

SKYLIGHTS.

Nearly every large mill is dark in the middle; none need or should be. Builders depend too much upon side-wall windows. One skylight in the roof is better than four side-wall windows. Fig. 4 shows a cheap skylight, set flush with the shakes, which I have used successfully even in heavy snow countries on half-pitch roofs. The glass was ordinary 21-ounce plain. It does not leak, and the snow slides over it. Whitewash the walls and ceiling. Have a well-lighted mill day and night.

WARMTH OF BUILDING.

The plate and concentrator rooms should be built so as to be warm in the winter season. Never have a drafty mill. Icicles do not aid plate amalgamation. A few dollars spent in tarred paper on the walls will be a wise investment in cold countries. A generous stove, with a couple of hot-air drums 10 feet long by 30 inches in diameter, will prove economical of wood and keep a 20-stamp mill building comfortable and fit for amalgamation.

Light and warmth are not luxuries; they are the necessaries of the business.

TABLES.

Tables should be heavy and solid. Flimsy tables, made of thin boards and light scantling, get out of true. Figs. 2 and 3 show a table fastened to the floor. This form has advantages over the rolling table. Ordinarily, 12 feet long by 5 feet wide will suffice. Ten feet of this is nailed to the floor. The 30-inch apron is removable to allow setting in shoes and dies.

The frame is of three pieces, 4 x 6 inches by 10 feet, dressed on the upper edge and notched down $\frac{1}{2}$ inch every 2 feet. The boards are $1\frac{1}{2}$ inches thick, 2 feet wide, 5 feet long, dressed on

upper side, edges and ends. After dressing true, cross-plane the board so that there shall be a fall of $\frac{1}{16}$ inch from ends to center. Each board is butted snug to the one next above it and nailed or screwed to the 4 x 6-inch, the ends of the boards being flush with the outer edge of the outside 4 x 6-inch. The side rail is a plank $1\frac{1}{2}$ x 10 inches nailed against the side of the 4 x 6-inch, and forming a tight joint against the ends of the boards. To prevent leaking, bruise the edges of the boards with a blunt chisel, the blade 2 or 3 inches wide and $\frac{1}{4}$ inch thick. As soon as the table is wet these bruises swell.

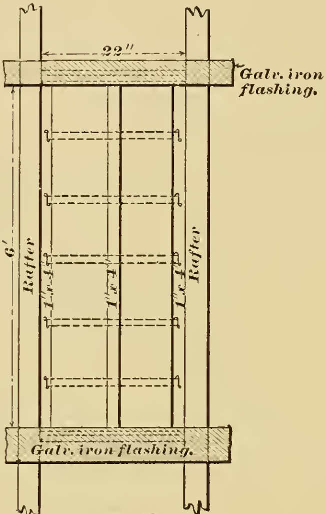


Figure 4.

Dotted lines show glass, 21 oz. plain, overlapped and kept in place by galvanized hooks, Putty under the glass.
Finish with strips of $\frac{1}{32}$ sheet lead flashing extending over the rafters and under the shakes.
The sash frame of rough 1″ x 4″ nailed to rafters.

At the foot of the table, Fig. 2, is a double drain box with sheet iron flap. While the mill is running the pulp flows into box *a*, thence to concentrators through a 2-inch pipe, the end of the pipe projecting $\frac{1}{2}$ inch above the bottom of the box *a*, thus forming a sufficient quicksilver trap. When brushing up the flap is lowered and the washings go over into box *b*, whence they overflow through notches into box *a*.

These double drain boxes will, under careful milling, recover $25 to $50 per month in amalgam which would otherwise be swamped in the concentrates or lost in the canyon. Under slipshod milling this box catchment might easily pay the mill payroll. This for twenty stamps.

Fig. 2 shows the arrangement of the splashboard.

By using a lip plate 17 inches wide, set on grade of 4 inches to the foot, there will be no clogging with sand and sulphurets, and the amalgam catchment will be heavy. Foundries ordinarily cast a mortar with $1\frac{1}{2}$ inches to foot grade on the lip. This will surely clog and prevent the amalgam from catching on the lip plate.

Let the pulp drop from the mortar lip (usually $1\frac{1}{2}$ to 3-inch drop) upon a sheet iron strip 6 inches wide, whence it flows upon the copper plate. A drop of over $\frac{1}{2}$ inch will scour the silver. Under the splashboard B a 4-inch strip of sheet iron is set over the plate to prevent scour.

LAUNDERS.

If of wood, let the launders be V shape, set to grade of $1\frac{1}{2}$ inches to foot.

ROCK BREAKERS.

Every mill should have two rock breakers, one coarse and one fine. Set the jaws of the coarse breaker 4 inches apart, so that a sledge can slide through, thereby avoiding the breaking of the pitman or side rods. Dump all the ore, coarse and fine, as it comes from the mine, directly into this large breaker. The mixing of fine with coarse ore prolongs the life of the jaws. The crushed ore is to pass over a grizzly; the fine going to the feeders, the coarse to be crushed in a second breaker. Manganese is the most durable for jaws and for mortar liners.

GRIZZLY.

Grizzlies often give much trouble by clogging, the rock building against the thimbles. The most satisfactory that I have ever used is made of 12 or 16-pound T rail, downside up, bars 6 to 8 feet long, $1\frac{1}{4}$ inches apart, at an angle of 42° to 45°, the lower end of the rails rolled over, as in Fig. 5. If not over 8 feet long it will be unnecessary to use a middle bar with its thimbles. The steep grade will give a fine product, and there will be only occasional clogging.

So much for the working tools. Select a mill site with plenty of fall; not less than 55 feet from track level to concentrator floor; better 75 feet. Heavy duty is exacted. Machinery is sure to break, therefore the working parts must be accessible.

MILLING.

I hold fast to four central ideas: First, on free gold ores the mortar has the two functions of crushing and of amalgamating. Second, on ores running less than $12 per ton the method used

must be such as to extract practically all the recoverable gold. (We will not now discuss $40 ore.) Third, if the ore is hard enough to require a rock breaker, build a heavy stamp mill, otherwise you may use one of the various rotary mills. Fourth, do not try to economize on rock breakers. It is the cheapest initial crushing; one to the mill is not enough.

There is a good deal said nowadays about high duty of mill,—*i.e.*, large crushing. I believe in high duty consistent with full

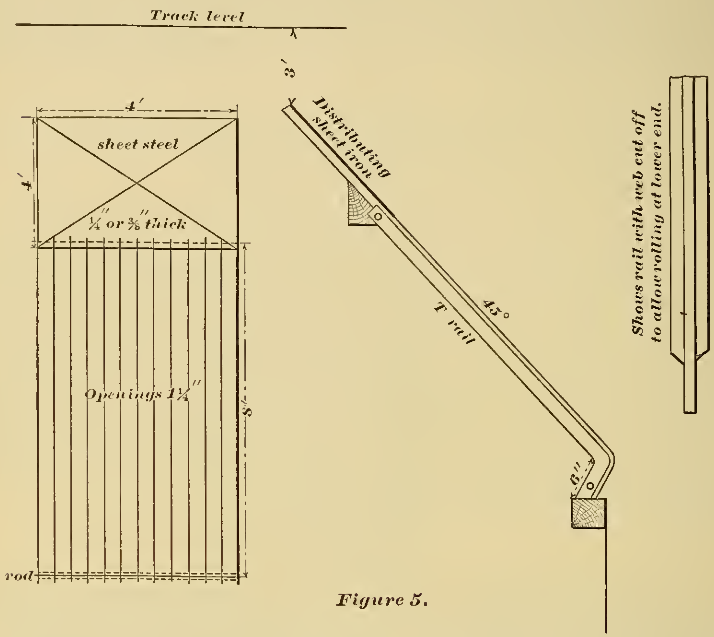


Figure 5.

Grizzly. To screen ore that has already been crushed in large breaker if mine produces coarse chunks.

recovery of the gold, but I cannot indorse a given type of mortar merely because it is a rapid crusher. High duty should mean low tailings.

The narrow, straight-back mortar, with low discharge, is not a new idea. The foundries are full of old patterns of this type. All our cement gravel mills are so built, but it is not enough to crush rock; one must also catch gold. High-grade tailings result from the sacrifice of amalgamation to crushing.

Taking up now seriatim these four captions:

The mortar has the two functions of crushing and amalgamation. Gold amalgam is a slippery eel; it rolls and floats unless fairly treated. Give it opportunity and it will settle in the mortar. It is not so hard to catch fine gold inside the mortar if the mortar

is built for that purpose. The limit of crushing in a given mortar must be measured by the percentage of inside amalgamation, except, however, on ores carrying values of $1.00 to $1.50 per ton of fine light gold. The aim should be to increase the inside catchment above 60 per cent. The tendency of stamping is to combine the gold with the mercury. It is natural that this amalgam should stay inside, and it will unless the millman expels it in his struggle to secure a high crushing duty.

Extract practically all the recoverable gold. Whoever has used quicksilver has lost gold. Whoever has crushed ore has had uncrushed particles of sand carry some atoms of gold stowed away inside the particles. Therefore, tailings must assay something. It is a commercial question. You may be able to afford some loss in order to get through a larger tonnage. To illustrate:

Preparing a tailings sample for assay by screening through a 40-mesh screen, we find that 2 per cent. of the sand rests on the screen, and the fire assay shows values of 5 cents or 10 cents per ton in the fine sands and $1.50 per ton in the coarse.

The results may be tabulated:

98 tons @ $0.05	= $4.90	or @ $0.10 =	$9.80
2 tons @ 1.50	= 3.00		3.00
100 tons	= $7.90		= $12.80

i.e., $0.08 to $0.13 per ton.

I am quoting actual results, not giving theories. The crushing was at the rate of 3 tons per stamp through a No. 2 tin screen.

This 2 per cent. coarse sand could have been saved by using No. 1 tin, but it would have been at reduced crushing tonnage, and would have come close to the sliming danger.

I call this extracting practically all the recoverable gold, and to increase this crushing to 5½ tons and the tailings to 75 cents per ton would be business suicide, whether there were 10,000 or 10,000,000 tons in the mine.

Use stamp mills on quartz. Some one will probably invent a better machine than the California quartz mill for crushing rock and catching gold. It has its faults, and yet its much-condemned sliming tendency is too often the fault of the millman. It is simple, relentless and conscientious, with fewer faults than cling to many of its operators.

It is easy to stir mud, but if you have rock to crush build a heavy California stamp mill, with the shoe 9½ inches and the die 9¾ inches diameter; the whole stamp weighing 1100 pounds, 10½

inches from center to center of stems. The ends of the mortar, after the liners are in, should be flush with the screen opening.

I have heard more than one man assert that his ore did not require a heavy stamp, but I have always found that such men had never tried the two weights on the same ore. If the ore at one mine happened to be harder than at another they would endeavor to effect a cure by giving more drop to the light stamp. If the rock still resisted and the stamp bounced they would settle back on the excuse that they had very hard ore.

I have had an 850-pound and a 1100-pound stamp on the same line shaft and on identical ore. The former crushed $1\frac{1}{4}$ to $1\frac{1}{2}$ tons per stamp, and the latter 3 to 4 tons per stamp. The light stamp could not do the work, no matter what drop I gave it.

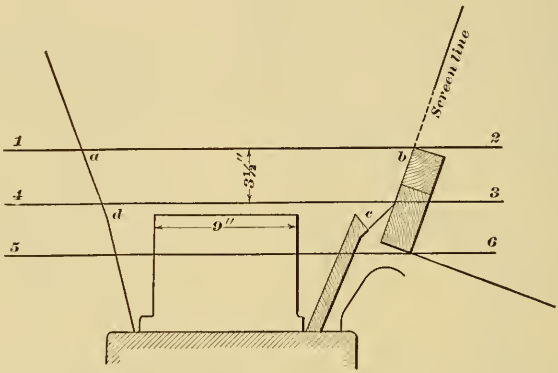


Figure 6.

Now, then, how fast shall we run this heavy mill? What drop shall we give it?

I want a heavy stamp because I do not want to waste time breaking rock. I want a shoe and die of large area, so as to embrace many pieces of rock at every blow. If you reduce the crushing area from $9\frac{3}{4}$ to 8 inches you are compelled to make up the deficit by speed or by a long drop.

Bring a sledge upon a bowlder. If you don't break it, you make the next blow harder, but you don't hit oftener. Probably you will strike lower. You accomplish your result by muscle, not by agility.

So it must be with a stamp mill. Stamp crushing is not a question of spalling rock; its object is to crush and amalgamate ore that has been, as it were, already spalled by the rock breaker.

I am now running a mill upon unusually tough, hard ore; first-class road metal some of it. With a speed of 92 to 94 and a

drop of 6 to 7 inches, a 1100-pound stamp will crush about 80 tons in twenty-eight days and save all the gold. Increase the speed to 100 or 102 and the drop to 8 or 9 inches, and this same stamp will crush about 110 tons in twenty-eight days and by no means save all the gold.

So, then, my rule is to get weight and area of stamp, so as not to waste time, and to drop as the tailings assays dictate.

High speed means more wear and tear, hot boxes, greater percentage of breakdowns. If you can reach the limit of profitable amalgamation by a slower speed, why not do it?

I have never run a stamp heavier than 1120 pounds, and I regard that weight as sufficient.

I have found it easy to crush more than I can amalgamate. It is for this reason that I am unable to give assent to the practice of installing a system of rolls and crushers so as to deliver a cracked-corn product to the stamps. For some mysterious reason there is benefit to amalgamation by churning rock in a mortar. I am no sufferer if it does take a little more time in the making of the butter. If the mine needs more stamps, buy them.

Before a 5-stamp battery, 5 feet width of plate seems to be the practical limit. Six feet is too wide, and 5 will give better results than 4.

I have tried a launder before ten stamps, the pulp being thence passed to three tables, each 4 feet wide. This was a failure. By no adjustment of gates and water could even distribution and flow be obtained. One table was all sand, and another all slimes. The wave, the crescent bow, was not there.

Provide rock breakers liberally. One breaker to the mill is the rule, and ordinarily this means that much of the ore going into the feeders will not pass a 2½-inch ring. It would not cost much to cut this product to 1-inch ring size, and a very noticeable increase in crushing will result. With a 1-inch ring product there will be fewer broken stems and consequent delays.

The rock-breaker end of the mill is too much neglected. One is not enough to any mill. On the other hand, I see no gain in going to the other extreme of too minute rock-breaker crushing.

The following rules are suggested:

Catch the gold close to the die.

Don't use chock-blocks or inside coppers.

Don't slime by too fine crushing.

Don't crowd tables with too much pulp.

Don't sluice the pulp over the plates.

Don't add water outside the mortars.

Don't be afraid of steep grade to tables.

Use no distributing boxes.

Don't turn all the pulp on one-half the plate area when brushing up.

Don't scrape plates with chisel or rubber. Rub up with a cotton cloth and tepid water. Lip plate, however, is scraped off monthly with a chisel.

Feed quicksilver so carefully that never a free globule appears on the plates.

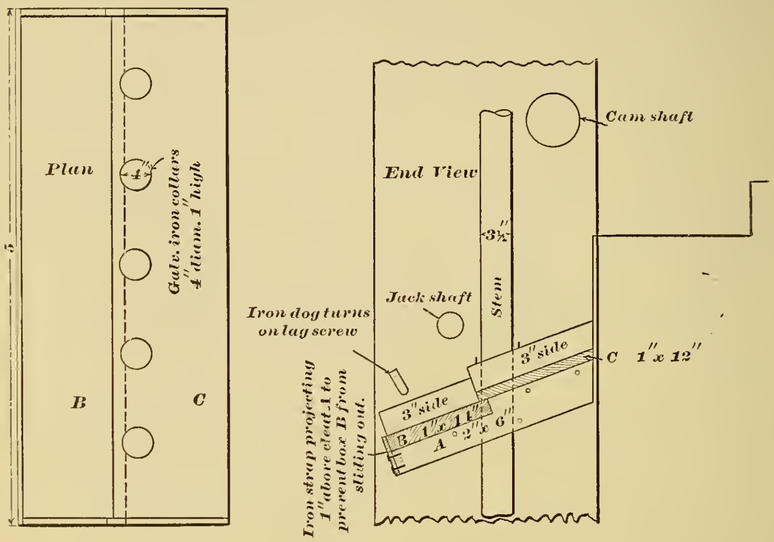


Figure 7.

Grease boxes over mortars.

Two cleats, A, are lag-screwed to the battery posts. The boxes, B and C, 3" deep and lined with galvanized iron, rest upon these cleats and fit snug between the posts. C is screwed to cleat A. B is removable and is held down by the iron dog.

The galvanized collars prevent grease from working down upon the mortar housings.

Feed low,—*i.e.*, regulate the feeder so that the shoe is kept just cushioning on the die.

Run the batteries with the splash, and not with the wave motion,—*i.e.*, lift the shoe above the water at every blow.

Use automatic sampler on tailings.

Avoid the use of acids and cyanide on plates; common lye will cut grease.

Keep the quicksilver clean by retorting, and then washing well with dry lime; follow this treatment with thorough washing in clean water.

Use well-silvered plates. When they turn green, replate them; and don't waste time and gold over nostrums.

Catch the gold close to the die. This requires a roomy, rather than a narrow, mortar. You can't churn butter in a teacup, and you must churn if you want to amalgamate. I am now using two styles, both 1100-pound batteries. There is no difference in crushing, but the mortar shown in Fig. 1 invariably makes the larger inside catchment. The other mortar has a straight back.

Whenever I neglect my inside catchment the tailings run up. Set the discharge too low and the mortar will throw out on the plates. It is the province of the plates to catch the fine gold, not the coarse. Coarse gold will roll down hill, and the table is a downhill proposition. Coarse gold makes good-sized bits of amalgam, and the natural habitat of these is inside the mortar.

On quartz the discharge must not be less than $5\frac{1}{4}$ inches at the start,—*i.e.*, $5\frac{1}{4}$ inches depth of water measured from the top of the die to the bottom of the screen opening. Starting with this, you will soon have $5\frac{3}{4}$ inches discharge. We will say now that the wear of the die is 2 inches in twenty-eight days. This would mean $7\frac{1}{4}$ inches discharge at close of the run, and would diminish the crushing.

To cure this make one screen frame with 3-inch strip on bottom and 2 inches on top edge; make another screen with a 1-inch strip on bottom.

As the run progresses you can change and turn screens so as to preserve a practically uniform discharge.

The drop is regulated by the tappet.

There is no harm in using a $6\frac{1}{2}$ to $7\frac{1}{2}$-inch discharge. But there is no gain to amalgamation, and you diminish the crushing capacity of the mill. In other words, work so as to obey the injunction, "Get through all possible consistent with full recovery of the gold."

Some interesting experiments were made at the Utica and Gwin mines on mortar shapes for 900-pound stamps. The back of the mortar was straightened to 77°. At the discharge line the distance from shoe to back is $2\frac{1}{4}$ inches, and to screen $5\frac{1}{2}$ inches. It was found that this mortar would crush 5 to $5\frac{1}{2}$ tons to the stamp on Utica and Gwin ores, whereas the wide mortar crushed 4 to $4\frac{1}{4}$ tons; this with No. 2 tin.

I attempted to apply these lines to an 1100-pound mill, but did not increase the crushing; and can only attribute the failure to the fact that the heavier and larger shoe makes a more vicious splash. You cannot bring the screen closer than $7\frac{1}{2}$ inches to the shoe. On identical ore the mortar shown in Fig. 1 will outcrush this straight-back Utica mortar, because of the greater weight and shoe area, and it is a better amalgamator.

No chock block or inside coppers. A copper plate in the mortar will attract amalgam. But copper is no better magnet than is amalgam itself. Start a bed of amalgam in some secure cranny around the dies, and you will have as eager an ally. Grooves in the liners only shorten the life of the liner.

Everyone who has used a chock block has seen it build with amalgam, and has also seen it scoured red, in whole or in spots; scoured, we are told, accidentally. Let us dissect this "accident."

Every battery is liable to be filled up with sand. Feeders fail, faucets choke, millmen yawn or are busy elsewhere; no matter the reason, true it certainly is that every battery fills up sometimes. It is this fill of sand that scours the chock block. Amalgam, once scoured off, is rebellious metal. It is round and hard; it gets out on the plates, where it rolls and tumbles, scorning to stick, content only when it lands in the concentrates or in the canyon. If in the canyon it is lost for all time. The millman blames the accident he himself has concocted, *for the chock block lies within the zone of scour.* Study Fig. 6.

Particles of gold and amalgam are flying about within the area *a, b, c, d*.

These particles can be attracted upward to the chock block or downward below the line 3-4, as you please. If you use a chock block they will fly to it. If you don't they will sink around rocks. Every particle lodged will attract another; soon it will be a mass. But note the difference. The chock block lying within the zone of scour 1, 2, 3, 4, your caught amalgam is in danger of loss. The zone 3, 4, 5, 6 being below the line of scour, your caught amalgam is safe till clean-up day. Millmen may sleep, faucets clog, feeders buck; your amalgam is safe.

Repeatedly do I find the entire front of my mortar, below the line 3-4, one mass of amalgam, in cakes ¼ to ⅝ inch thick; this on $5 to $7 ore.

Take the year through, and you will catch more gold inside without chock blocks than with them.

Another important advantage is that, in case of overfeed of quicksilver, this excess will be safely absorbed by the mass of amalgam around the dies. Excess of quicksilver on a chock block is fatal; it sloughs off the amalgam.

When one considers the varied duties of the millman, and the sudden variations of gold ores, there is full warrant for abandoning the chock block.

Don't slime by too fine crushing. Especially vicious is this practice on slate ores. The correction can be located only by assaying the tailings through different meshes.

If you slime you are also wasting power by dead—*i.e.*, useless—stamping.

Don't crowd plates with too much pulp.

Don't sluice the pulp over the plates.

Don't be afraid of steep tables.

No distributing boxes.

Don't add water outside the mortar.

These five rules may be treated together.

It is not easy to set down in words just what the conditions of the pulp should be. It is a question to be determined by the eye.

If you will let the mind dwell upon these negatives some idea of my meaning may be realized.

Plate amalgamation and ground sluicing are different arts. Gold is caught on plates because gravity settles the metal to the silvered surface. Therefore, don't be in a hurry to get rid of the sand, and don't throw obstacles in the way of the laws of gravity. Gold and mercury have their full share of specific gravity, but reverse the conditions and you easily offset this factor.

The pulp must not be too thick on the plates; you don't want a double deck of sand. Furthermore, there should be an even flow of water over the entire plate area. It is for this reason that the center of my plate is $\frac{1}{16}$ inch below the edges. Batteries tend to a greater discharge in the corners than in the center. It is a common sight to find a rush of water 4 to 6 inches wide along both edges of the table; one-fifth to one-fourth of the plate area is overflooded.

Many mills have tables 24 feet long, with no break in grade. Drop a cork chip at the head of such a table and at the same instant another chip at the middle. You will find that the second cork will travel its 12 feet in less time than the first one, because the velocity of flow must be accelerated on such a table. If the flow is correct for the first 12 feet, it must be wrong for the second 12 feet.

It goes without saying that tables should be of uniform width from top to bottom.

The sand should move over the plates slowly and evenly. The water will go in waves or pulses, while the sand below it will be kicked along by these successive waves, not moving any faster over the last 2 feet than it does over the first 2 feet of the table. Between the waves the sand almost, but not quite, comes to a standstill. Note this point especially: The sand is kicked along; it must never be swept along by a heavy flow of water.

Have a wave and use it. It is these successive kicks that tumbles the sand about. Before the last plate is reached the gold is kicked into its proper place,—viz, to some sticking point. The

$\frac{1}{2}$-inch drop every 2 feet assists the process in two ways: (a) The drop bowls the particles over; (b) it prevents acceleration of flow.

With this thin, carefully regulated flow and a sticky, pasty plate good amalgamation will be had.

One reason for the excessive use of water, so common, is that the table has too little grade.

The millwright turns over a table $1\frac{1}{4}$ to $1\frac{1}{2}$-inch grade to the foot. It should be $2\frac{1}{2}$ to $2\frac{3}{4}$-inch.

Don't be afraid of steep grades, for it means less water and clean table; no danger of scour.

Distributing boxes are an abomination. The holes get plugged up. They incite the millman to careless use of quicksilver when rubbing up. They are traps to gather quicksilver, and let it out in lumps on the plates. They don't distribute pulp as evenly as the plain splashboard (Fig. 2).

Globules of free quicksilver on the plates should never be tolerated. If there is a distributing box the millman can lay the blame to the box. Take away the box and rob him of his excuse.

Don't add water outside the mortar. One needs just the same amount of water inside the mortar as out, and I use just enough water in the mortar to move the pulp properly over the plates. No reliance can be placed upon stated formulæ of so many gallons per ton of ore.

The quantity of water is vital, and nine millmen in ten use too much.

Don't turn all the pulp on half the plate area when brushing up.

We have all seen the 4-foot plate with partition strip in center. The battery is not hung up when brushing the plates, but all the pulp is turned to one side of the strip while the men are working on the opposite side.

It seems to me there can be no logical defense for this custom. If 4 feet width is needed at any moment, it is for all the moments. To confine all the flow to 2 feet width must inevitably scour. The only excuse urged is that it does not pay to hang up. I hardly think it pays any better to scour; the richer the ore the greater the loss. Build another battery if the mine will stand it. The average mine will survive the shock of a little hanging up.

The champions of the never-hang-up theory seldom, if ever, sample tailings when brushing up. They don't know their own losses. It is a well-known fact that upon ore of only $8 value the plates, just before brushing up, will be plentifully sprinkled with coarse bits of amalgam barely hanging on against the flow. I suggest, by way of proof, that three tailings samples be taken

from the 4-foot plate width within the ten minutes preceding the rubbing up, and then three samples from the 2-foot plate width during the ten minutes of rubbing up. Do this for thirty days, making careful assays of all the samples. Note the per cent. of assays abnormally high, due to particles of amalgam.

It is not sufficient to reply that what is lost in amalgam is recovered in the concentrates.

Every concentrator passes more or less of amalgam and mercury over into the tail race.

Don't scrape main plates with chisels.

Allow no globules of free quicksilver on plates.

It is essential to keep a well-silvered surface, sticky and pasty. The apron plate may require replating every three or four months. The lower plates should wear several years. The cost of replating varies with the ore. I have found it amounts to from 1 to 1½ cents per ton crushed, using a plating of three ounces silver per square foot of plate.

Every morning I take off the excess of amalgam, but never skin it closely. Rub up with a piece of cotton domestic several folds thick, sprinkling the plate with quicksilver from a small shaking bottle. I have seen used a beer bottle with a quill through the cork, but this is malpractice. Use a small vaseline jar with a piece of cotton tied taut over the mouth, and have clear, tepid water in a kettle to dip the rag in frequently. Rub the plate briskly and thoroughly, being careful every day to remove all blisters of amalgam. These blisters eat out the silver, and therefore should not be permitted to form. In cold weather they are especially troublesome. If they stick too tight for the rag, they may be gently scraped off with a piece of No. 24 stovepipe iron shaped like a flat scoop 2 inches wide. Do not use a steel chisel. Finish with a final light sprinkling from the jar and thorough rubbing with the cotton rag; then brush over with a whisk broom.

The lip plates are never softened with quicksilver, but are every morning brushed off, or rather scrubbed off with the broom, to clean out the sulphurets. The lips will stand a good stiff brushing daily.

At 4 o'clock P.M. and at midnight my plates are again rubbed up, but no amalgam is taken off at these times. It therefore takes only a few moments for these two rubbings. My running time on a 20-stamp mill is twenty-three hours daily, because of this careful plate treatment.

There are never any globules of free quicksilver on the plates, top or bottom. If the ore is lean we feed less in the battery, and

the rubbing up is so carefully done that it never leaves drops of quicksilver on the plates.

The quicksilver fed is weighed at every shift in troy ounces, and a daily record is kept. I never weigh out an allowance to my millmen. They know what is expected, and careless work reveals itself immediately on a plate. At clean-up there should be little or no free quicksilver in the mortars around the dies.

Battery water at 55° F. will give good results. It is essential to avoid sudden changes. I never saw a reliable mechanical heater. Perhaps, where oil is cheap, the incubator lamp would work.

I rely upon keeping the plate room warm because I am afraid of the sloughing off of amalgam, which inevitably follows a sudden rise of 20° to 30° in the temperature of the water. I am still studying the problem of keeping the water uniformly at 65°.

AUTOMATIC SAMPLING.

The custom of sampling tailings with a dipper by hand every half-hour, more or less, has but little to commend it.

It is to the owner's interest to know exactly what the tailings assay. It is to the millman's interest to keep the tailings low.

The hand sampler will soon learn how to sample judiciously, from his point of view, but no one can coach an automatic sampler driven by machinery.

It is absurd to take off the sample by hand from the tail of the vanner.

Several kinds of excellent automatic samplers are in use, but I will not take the time to describe them. However the sample be taken, it should be evaporated to dryness for the assayer. Do not pour off the clear water; you may use a siphon.

CLEAN-UP APPARATUS.

To clean up I use a wooden trough 5 x 2 x 2 feet; a man with the hoe; a 49 rocker, 4 feet long by 16 inches wide; a clean-up board 5 feet long by 12 inches wide, with 3-inch side rails, covered with a silvered plate; a buck and a wedgewood mortar; a small iron screen $\frac{1}{8}$-inch mesh.

Into the trough throw all the mortar dirt; sprinkle freely with quicksilver; turn in boiling water; then hoe the mass about thoroughly with hoe and strong four-tined rake, so as to break up all lumps. The dirt is then rocked out, and the resultant amalgam, iron scraps and fine sands dumped upon the clean-up board, and the sand washed out with a hose stream. The iron is taken out by magnet. Grind the amalgam a few minutes in the buck mortar;

rewash on the board, giving a final bath of quicksilver in a wedgewood mortar to skim off the dross. To make sure there are no lumps or bits of iron, copper or brass, strain through the ⅛-inch screen and regrind the lumps.

By this process two men will in two hours clean up a 20-stamp mill and leave not over $50 in the sands.

These sands are, of course, put back in the batteries at the following run.

I would clean up a 100 or a 500-stamp mill by the same process, except that the mixing would be done by what the macadamizing men call a "rattler" or revolving trommel; rattler and rocker to be driven by power.

Clean-up barrels and pans flour the quicksilver, and thereby entail unnecessary losses of gold.

The clean-up room should have a cement floor. All wash water should pass into settling boxes or tanks.

CONCENTRATORS.

Concentration is too broad a question to be discussed here; so much depends upon the characteristics of the metals and the gangues.

In too many mills the crew is inadequate, so that both batteries and vanners suffer alternately as the solitary millman trots up and down stairs vainly attempting to do the work of several men. I never saw a dozen belt vanners in any mill all working right for over five minutes at a time.

For the average gold mill the concentrator should not be oversensitive. There is a wide difference in this respect between the various belt vanners. Don't pay much heed to the advertised competitive tests.

It is because of their extreme sensitiveness to variance of load or water that I am disposed to think that the reign of the belt vanner is about over.

What is wanted is a machine that will not go awry at every little variance of pulp.

The belt vanner seems to require some experienced hand camped alongside it all the time. In that way the makers conduct their misleading competitive tests.

The Wilfley concentrator requires a heavy load—20 to 40 tons—to do effective work, consequently there would seem to be no room for it in a 5-stamp mill. Possibly a smaller table would scale down to, say, a 10-ton load. Manifestly, any concentrator

with so wide a range as 20 to 40 tons will not be going wrong every five minutes.

It is worthy of investigation, and it is idle to object that it has no belt.

COSTS.

To close, I present some details of cost per ton in a 20-stamp mill, based upon a year's average,—16,000 tons,—with freight at $1.10 per cwt. from San Francisco; wages of amalgamators, $3.50; of rock-breaker men, $3:

Water power: rock breakers	$0.0102
Water power: batteries	.0884
Labor, all, including repairs	.2862
Shoes, dies, mortar, liners	.0721
Oil: light and lubricating	.0131
Replating	.0100
Sundries	.0024
Firewood (4600 feet altitude)	.0081
Rock-breaker jaws, tappets, bosses, extras	.0130
Quicksilver loss, 0.145 troy ounce per ton	.0052
Total per ton crushed	$0.5087

Quicksilver loss includes the mechanical losses from retorting, cleaning up, etc. The tailings ran from 5 to 20 cents. The ore at the monthly clean-ups ran from $4.75 to $10.25 per ton.

RECAPITULATION.

Use a stamp mill because no better machine for the purpose has been invented.

Use a heavy stamp because it won't waste time, and can be run slow enough to save wear and yet fast enough to churn, and therefore amalgamate.

Have large shoe and die areas, so as to embrace plenty of rock at every blow.

Crush and also amalgamate, the limit of your crushing to be taught by the tailings assays.

Extract all the practically recoverable gold. If more stamps are needed, build them.

The speed and drop suitable can be determined only by assaying tailings.

Catch the gold close to the die.

Renounce chock blocks.

Don't slime by too fine crushing.

Beware of too much water.

Don't crowd the plate with too much pulp.

Have the plate sticky and pasty with amalgam, and never dripping with quicksilver.

Use a broad, steep plate, and hang up when rubbing up. Note the use of the word rub, not wipe. Put elbow grease, and no other, on the plates.

Don't be parsimonious about replating.

Sample automatically.

Keep the battery water temperature not below 50° F.; better at 65° or 70°.

ON THE NEED OF EDUCATION OF THE JUDGMENT IN DEALING WITH TECHNICAL MATTERS.

By George W. Dickie, Member of the Technical Society of the Pacific Coast.

[Read before the Society, December 7, 1900.*]

Of all teachable things, the education of the judgment receives the least attention, while its importance is supreme. I do not know of a single university that has a chair of common sense, and in trying to reason out why this so important endowment is not taught I can think of but one reason, and that is the impossibility of finding a man to fill such a chair.

Men in all professions are therefore left to acquire this most important part of their education as they acquire practical experience, and in most cases with as little success.

It is an unfortunate condition with us that we are nearing the end of our work before we realize how important a factor judgment is in all questions of importance that come before us in our everyday experience.

Self-education in the matter of judgment is a life-long mental discipline. One of the most important points in this process is very difficult to deal with, for every time it comes up it involves us in an internal struggle which equally affects our vanity and our ease.

This point consists in the tendency to self-deception in regard to the result we wish for. For any one who is not brought daily to the necessity of self-correction in regard to this tendency, it is impossible to realize how all-powerful the tendency is, and how unconsciously we all yield to it. How eager we all are to seek for such evidence as may be in favor of what we want the result to be and to disregard any evidence pointing the other way. We receive as friendly that which agrees with our preconceived notions, and resist and dislike that which opposes them.

In fact, the inclinations we exhibit to receive and to act upon any report or opinion that harmonizes with our preconceived notions can be compared, in degree, only with the incredulity we entertain toward everything that opposes them. And all this goes on unconsciously, while we honestly believe that our judgment is entirely free and unbiased.

It is my purpose to try, in as simple and direct language as I am able to use, to point out some of the ways in which we fail to exhibit sound judgment in dealing with the engineering problems that confront us every day.

*Manuscript received December 13, 1900.—Secretary, Ass'n of Eng. Socs.

In my work, how do I suffer from lack of judgment on the part of myself and those connected with me, and how could much of that suffering be avoided, thereby reaching results with less waste of labor and time? This is an inquiry worth making, even if the answer be not quite satisfactory.

There is fast growing up a system which, if I understand the direction in which it is moving, proposes to dispense with the necessity for the exercise of judgment in dealing with everyday engineering problems. Young men without experience, and who have never had the chance to acquire an educated judgment, are, as a rule, put in charge of very important work, and a set of instructions is provided for their guidance, which instructions are supposed, if rightly carried out, to obviate the necessity for any exercise of judgment on the part of the person in charge.

Those of us who are carrying out large contracts with the Government and with some public companies find it hardly possible to get anything decided by sound judgment based on experience. I have often tried to reason from my own experience with young inspectors of work, but that kind of reasoning is not now admissible. Printed instructions are produced, with the intimation that these must be adhered to in every particular, the inspector having no discretion in the matter. I have often traced these printed instructions back to their source, and found the author to be a man whom I would not like to trust with doing the work covered by them.

In mechanical engineering and kindred business, such as shipbuilding, the great bulk of the designing is done by the contractor, all working plans being prepared by him. He is also held responsible for the result; yet all his plans must be submitted to a young and, from the very nature of the case, inexperienced inspector, who, however clever he may be in solving theoretical questions relating to the device in question, has never had to make those things himself and to be responsible for their working after being made, and for their costing no more than he said they would cost before he began.

Now, the young inspector reads in his book of instructions, generally in a preface, that the object of printing these instructions is for the proper protection of the interests of the Government.

In a decision by the Judge Advocate of the United States navy, I read the other day that the aim and intent of the wording of the specifications and contract for the building of a warship were solely to protect the interests of the Government.

Now, my idea has always been that the object of the specifications and contract, when fully carried out, was to produce the best

possible warship of the kind specified; that there were two parties to the contract, and that the interests of one needed protection just as much as the other. The language used in the decision mentioned shows how difficult it is for an inspector to use sound judgment, even if he has it at his command. When a plan is presented to him by which you propose to carry out the object of the specification, he looks at it with the distrusting notion in his mind that you have used what skill you possess to design this part of the work as cheaply as possible, and that it is his business to stand between you and the object of your desire; and he will not reason with you as to the why and wherefore of your design without putting you on the defensive in regard to your own character instead of that of your design. And when he has found out where he can add something to your design, to increase its cost without spoiling it, he is very likely to do so, as he thereby tickles his own vanity by impressing you with his power and cuts you out of doing the thing with the simplicity and economy that you were planning for.

This shows the need of an educated judgment on the part of such an inspector. And of course it might be the other way. The contractor, in making his design, may allow his self-interest to rob him of all sound judgment, and his desire for a simple and cheap device may lead him into making something that would not properly meet the requirements of his contract. What is needed is an honest endeavor on both sides to cultivate the growth of a sound judgment that can decide technical questions altogether apart from the personal interests of the parties.

In no question is sound judgment, based on long experience, more necessary than in the many disputes that arise regarding workmanship and material. Here, where an educated judgment is most required, we find that self-interest and hard and fast rules interfere most with its application. When I look back over the many battles I have had with inspectors who demanded their pound of flesh when it could not possibly be got without blood,—sometimes all the judgment lacking on the one side, and sometimes on the other,—I wonder why we should continue beating the air over questions that with the exercise of a small amount of sound judgment would never be raised.

A good many years ago, while in the casting yard one morning, I noticed a propeller casting, a solid cast wheel which had, as many of them are apt to have, some gas checks across the back. I did not consider that the small defect should be any reason for condemning the casting. That was my judgment. Perhaps I was assisted in forming this judgment by a strong desire to save the

cost of another casting. When the superintending engineer of the company for which this wheel was made saw the casting, he promptly condemned it, and no amount of reasoning on my part could alter his judgment. There being no desire on his part to help his judgment to concur with mine, he would take no chances with a wheel having any visible defect. And he believed that my opinion was formed entirely on self-interest, while his was founded on the high plane of engineering prudence.

In this particular case I thought it worth while to test the foundation upon which each of us based our judgment. So I said to him, "Your company pays for this wheel 9 cents per pound, and it costs my company 6 cents. If I make another, we will lose 3 cents per pound instead of making 3 cents per pound. Now, I think that I am right in claiming that the slight defect in this casting is no ground for condemnation, but in order to save actual loss your company can have the present wheel for 6 cents per pound."

"Well," said he, "now you're talking reasonably. I will see our people about it and let you know." Within an hour this wheel was accepted and went into service, and, so far as I know, had a long and useful life.

Now, I myself might have acted just as this engineer did, but the transaction illustrates how much we are all influenced by our own desires in these questions instead of by sound judgment, and how difficult it is to know when the decision is prompted by desire when we think we are exercising our judgment.

Our whole modern method of testing and inspecting materials is founded on the belief that the faculty of judgment in an inspector is a dangerous thing, and that all excuse for its cultivation must be eliminated from his mental stock in trade.

The other day I saw condemned and broken up a large bronze casting that had cost about $3000, because the coupons or test pieces showed less tensile strength than the specifications required. The casting itself was perfectly sound and very tough; in fact, admirably suited for the purpose for which it was made, and not the slightest doubt of its character was expressed by any one who saw it. Yet, because the test piece was required to show 55,000 pounds tensile strength per sectional inch and broke at 44,000 pounds, a great deal of labor and costly material was deliberately destroyed, the inspector claiming that he had no discretion, which means no judgment, to exercise; and, when the case was appealed to a higher authority, that authority, who could not see this good piece of work, entirely suited for its place in the structure and with ample margin of strength, simply sent to destruction with the

careless remark, written officially from the other side of the country, that the requirements of the specifications must be fulfilled.

You must not understand me to mean that physical tests are not very important in deciding the quality of material, but when applied without judgment they may result in great waste of both labor and material, for they do not present the whole case, even as to the character of the material of which the test pieces themselves are made.

We often have plates of steel where the test pieces, cut directly from the plate, will give fine results, say 60,000 pounds tensile strength and elongation of 30 per cent. in 8 inches, and will double over on themselves without sign of fracture, and yet the plate itself would break like glass in bending over a large radius.

I have cut test pieces right out of plates that would not bend at all, and the test pieces would double over on themselves without sign of fracture.

Not long ago I had a plate of Government material to bend on the press for a keel plate, but the plate broke hopelessly in bending. There was no other plate to replace it of material that had been tested and accepted for Government use, and the inspector would not allow any other plate to be taken for the purpose.

I, however, took a plate of steel for merchant work and bent it to the required form with no sign of fracture. We cut a test piece out of the broken plate, right by the fracture, and it showed 61,000 pounds tensile strength and 28 per cent. elongation, and bent over on itself without fracture. Then we took a test piece out of the plate that had been successfully bent to the desired form and showed 62,000 pounds tensile strength and 22 per cent. elongation, and it broke before it had completely bent over on itself.

Therefore the perfectly bent plate was not allowed to be used because the test piece did not meet requirements.

Here the test intended to guard against the use of unsuited material resulted in preventing the use of eminently suitable material; not because of anything wrong in the test, but through the lack of judgment in applying the result of the test to the desired end.

I could multiply cases—they are of almost everyday occurrence—where the lack of judgment in regard to the value of tests results in needless loss and in great delay in carrying out work.

Lack of judgment is often manifested in a demand for unreasonably strict compliance with a specification that makes no allowance for ordinary imperfections in all products, even of the most skillful workmen.

Not many days ago I had such a case to deal with in building a small marine boiler for the Treasury Department under a very

strict specification. I found that it would make better work to weld the plate forming the sides of the combustion chamber, as the seam was in the way of the stays as shown in the drawing. The inspector thought so too, so the plate was welded; but the slight waste in heating resulted in the plate being one-thirty-second of an inch thin at the weld. I did not foresee this, but the inspector discovered that the plate was slightly thinner at the weld, and, the specification requiring a certain thickness of plate, the work was suspended until a decision should come from Washington. The decision came in due course and in the usual form, instructing the inspector to require the work according to the specifications.

Now, if this had been made as specified, with a riveted joint, its strength would have been, say, 67 per cent. of the plate, while the welded joint gave 92 per cent. Yet, notwithstanding all this, the work was condemned and thrown away.

This loss did not result from any desire on the part of the inspector or his superior to cause loss to the contractor, but simply from a failure on their part to apply sound judgment to the question before them.

A plan or specification is an instrument to be used for the production of a certain piece of engineering work. The thing produced is the only reason for the instrument being brought into existence, and when once the instrument has served its purpose its value disappears.

Yet engineers engaged to apply this instrument are, as a rule (especially the young men), more intent on applying the instrument than in considering what the instrument may be doing, forgetting that the instrument can of itself produce nothing, and that if not applied with judgment it will produce only such things as the man that made the instrument could himself produce. But, when applied with the correcting power of sound judgment, acquired in the production of similar things with other instruments, it becomes pliable in the hand of a master, and the result is the combined power of the instrument with the trained judgment of him that applies it.

All technical men engaged in producing tangible things out of ideas expressed in our defective language, interpreted by some one perhaps better acquainted with words than with things, and whose judgment has not been matured by any intimate knowledge of the actual work that the specification he is to enforce is intended to produce, feel how hard it is to get their position understood, and how often they must do things against their better judgment for fear it may be thought that their own interest, and not their experience, is the foundation on which their judgment rests.

OBITUARY.

John H. Blake.

By Frederick Brooks and William B. Fuller, Committee of the Boston Society of Civil Engineers.

John H. Blake, youngest son of Thomas and Mary Lowell (Barnard) Blake, was born December 5, 1808, at the South End of Boston, near where the Cathedral now is. His ancestors lived in Dorchester, in the old Blake house, now kept as a historical museum in charge of the Dorchester Historical Society. It is at Dorchester Five Corners, recently called Edward Everett Square, a short distance from where it originally stood.

John H. Blake was educated in the Boston public schools, being in the English High School in 1821 in the first class that entered the school.

The earlier portion of his business career was connected with chemistry and mining. He established a laboratory at Jamaica Plain, Mass., for the manufacture of pure chemicals. He and his brother-in-law, Otis Everett, Jr., were in partnership as chemists on South Market street down to about 1837. He made a journey to Peru in 1835 for the purpose of investigating the niter beds. He surveyed the Atacama region and explored an ancient cemetery at Arica, and made a collection of mummies and other interesting objects, which has been, since 1878, in the Peabody Museum of American Archæology and Ethnology at Cambridge. Drawings and descriptive notes by Mr. Blake were published in the second volume of the reports of the museum, pages 277 to 304, and in the annual report of the curator the collection is spoken of as one of the most important additions of the year. After Mr. Blake's return from South America he took charge of copper mines at San Fernando, Cuba, and he explored the Isle Royale* region at Lake Superior. In his office practice he was liberal in giving his professional brethren the benefit of his ideas, regarding that as his contribution to the advancement of science. He made suggestions to Babbitt about the alloy suitable for bearings, and to Goodyear about the vulcanization of India rubber.

About 1848 to 1864 Mr. Blake was in business as a consulting chemist and civil engineer in partnership with Franklin Darracott (who was a member of the Boston Society of Civil Engineers), with offices on State street and in Phœnix Building. Their business was largely gas engineering. They built the Worcester and

*The northeastern extremity of the island is called Blake's Point.

Lawrence gas works, which Mr. Blake organized. Mr. Blake was at one time president of five gas companies.

In the later part of his business career Mr. Blake became interested in street railways, and was president of the Metropolitan Railroad Company and of the Middlesex Railroad Company. He filled other important business and administrative positions.

He was elected a fellow of the American Academy of Arts and Sciences May 30, 1843.

Mr. Blake was one of the founders of the Boston Society of Civil Engineers, being one of the five who met at the preliminary meeting of April 26, 1848, and one of the committee to draft a constitution May 8, 1848. He was the first Secretary of the Society, his term of office being from July 3, 1848, to March 6, 1849. On April 4, 1849, he submitted for examination a model of a water meter. He wrote one of the earliest papers discussed before the Society on the use of lead pipes as service pipes. He was one of a committee who reported August 5, 1850, on the explosion of a locomotive boiler. Their report was printed in the *Boston Courier* of August 9, 1850. After the revival of the Society Mr. Blake was, with others of the earlier members, made an honorary member June 20, 1877.

His dominant characteristics were his simple faith, his courage, his kindliness, his love of truth and his earnest desire not to fail in doing his part of the world's work.

In his last years he was a confirmed invalid, but his mind remained active. He continued to reside in Boston with his son, Dr. Clarence J. Blake. He died July 5, 1899, in his ninety-first year. Within the next four months occurred the deaths of two of the other gentlemen with whom he had been engaged a half century before in the formation of the Boston Society of Civil Engineers, William S. Whitwell and Samuel Nott.

Frederick Brooks,
Wm. B. Fuller,
Committee of the Boston Society of Civil Engineers.

Roswell H. St. John.

By A. Lincoln Hyde, John W. Langley and A. H. Porter, a Committee of the Civil Engineers' Club of Cleveland.

Roswell H. St. John, a member of the Civil Engineers' Club of Cleveland, was born in Cincinnati, Ohio, in 1832. He was of English lineage, his ancestors having come to this country from England in 1700. While he was yet a boy his parents removed to Springfield, Ohio, where, after receiving a common school education, he learned the trade of watchmaker and jeweler. He was engaged later in this line of business in Bellefontaine, Ohio, and perfected various inventions applicable to his trade. Among these was the St. John universal chuck lathe, said to be the first foot lathe used by watchmakers.

At the breaking out of the war of the Rebellion, he was appointed member of the county military committee and later provost marshal for the fourth military district of Ohio. He continued in the latter position until the close of the war.

On the return of peace he again devoted himself to business, and became interested in sewing machines both as an inventor and manufacturer. He developed a number of valuable improvements in this line, and in 1877 the St. John sewing machine was perfected and a large factory for its manufacture was established at Springfield, Ohio.

Mr. St. John took up his residence in Cleveland in 1885, and shortly after commenced work on the typobar. He conceived the idea of making a type bar by what he termed the cold process, the bar being produced by pressing a solid body and a strip of flowing type metal together against assembled matrices, no heat being used. The operation forces a strip upon a tongue on the body of the bar and at the same time imprints the assembled characters upon the strip. The development of the process and a machine for its execution wholly engrossed Mr. St. John's time for the past ten years.

Mr. St. John took his completed machine to New York late in the year 1898, and the St. John Typobar Company, capitalized at $8,000,000, was organized by New York and Washington capitalists. A factory for the manufacture of his invention is to be built in Cleveland. Mr. St. John had just returned to the city and was engaged in the purchase of machinery for the plant a day or two before his death. He died of heart failure at his residence on Case avenue, July 27, 1900, after an illness of but a few hours.

Mr. St. John married in 1852, and his widow and four children, two sons and two daughters, survive him.

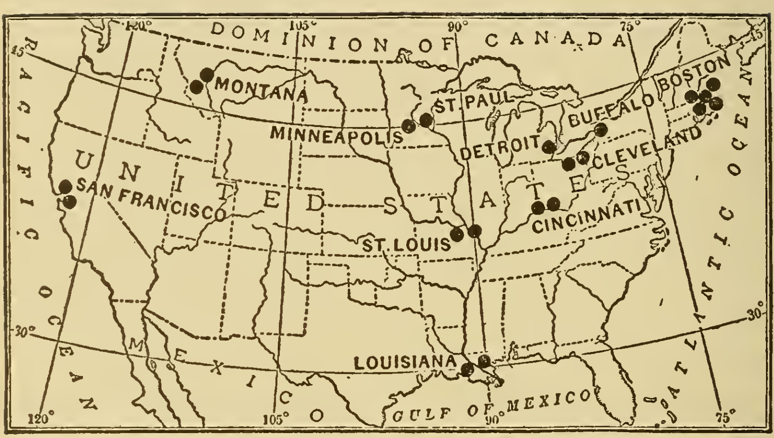
Mr. St. John became a member of the Civil Engineers' Club of Cleveland in 1890, and although not a regular attendant at the meetings, he ever had the best interests of the Club at heart, and was highly esteemed and respected by those members who came in contact with him.

It is fitting that the following resolutions to his memory be adopted:

WHEREAS, Roswell H. St. John, member of the Civil Engineers' Club of Cleveland, died on Friday, July 27, 1900; therefore, be it

Resolved, That this death has removed from us one of our esteemed members, and that the sincere sympathy of the Club be extended to the members of his family.

A. LINCOLN HYDE,
JOHN W. LANGLEY,
A. H. PORTER,
Committee of the Civil Engineers' Club of Cleveland.


DOMINION OF CANADA
UNITED STATES
MONTANA
ST. PAUL
MINNEAPOLIS
DETROIT
BUFFALO
BOSTON
CLEVELAND
SAN FRANCISCO
ST. LOUIS
CINCINNATI
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

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PROCEEDINGS.

Louisiana Engineering Society.

A special meeting of the Society was held on May 7, 1900, at 8.15 P.M., to take action upon the act prepared by the Legislative Committee for the Society to indorse.

President Malochee called the meeting to order with the following members present: Messrs. Coleman, Bell, Hardee, Ordway, Benson, Wright, Theard, Tutwiler, Flannagan, Jno. Richardson, Black and Lombard. There were also present, by invitation, two guests. Mr. William Woodward was the only architect who responded to the numerous invitations sent out to the architects of the city.

The Legislative Committee submitted a written report, placing before the Society a neatly and conveniently printed act regulating the practice of engineering and surveying, and asking the Society's indorsement of same. By motion, duly seconded, the report of the committee was received, and the act taken up section by section, with the understanding that any voting done by the members of the Society upon the amending or the approving of the act or any part of same was not to be considered binding upon such members to support the act, or *any* act looking for legislation, but was merely for the purpose of determining the proper and best form of act, in case it was subsequently determined to seek legislation, either with the indorsement of the Society or without it. After full discussion a few amendments were made.

A motion was then put and carried whereby the adoption of the act as amended, and in its entirety, was postponed until next Monday, May 14, when the regular monthly meeting will occur, in order to give the architects another chance to join us in a conference before we finally adopt any act. In the same motion the Secretary was instructed to issue notices of said conference for May 14, inviting all the practicing architects and others interested in the proposed legislation to attend not only the conference, but the meeting of the Society as well, and offering them the use of the floor during the conference.

Professor Woodward's views were listened to with interest. By a unanimous vote of those present the meeting hour next Monday was changed to 7.30 instead of 8 o'clock as usual.

The meeting then adjourned at 11 P.M.

Gervais Lombard, *Secretary.*

On May 14, 1900, the regular monthly meeting of the Society was called to order at 8 P.M. by President Malochee, with twenty-four members and ten guests present.

The minutes of the last regular monthly meeting and of the two special meetings of the Society held since were read and approved.

The minutes of the last regular monthly meeting of the Board of Direction were read for the information of the Society.

There was no report from the House Committee, but the Chairman of the Library Committee reported that the back numbers of the journals and magazines, which were ordered bound, were ready for the shelves and would be sent here in a day or two.

The Chair announced that he was sorry to inform those present that Mr. James C. Haugh, who was to have read a paper at this meeting upon "Pile Driving and Creosoting," was absent from the city, and that there would be no paper read to-night. Hereupon a motion was put and carried that Mr. Haugh be requested to read his paper at the next regular meeting of the Society, and that Mr. Hardee be asked to come prepared to read his paper, in case Mr. Haugh should be out of the city on that occasion.

The resolution introduced by Mr. Theard at the last meeting, and a notice of which was sent out with the notices of this meeting, was taken up for consideration, and after long discussion was voted upon and lost.

The amendment to the Constitution proposed by Mr. Theard, notice of which had been given in the same manner, was taken up, and by motion approved by the Society, and laid over till next meeting for second and final vote. It is as follows:

"To Article II, Section 3, of the Constitution, add: 'He can be transferred to the grade of member when qualified to become so under Section 2 of this article.'"

At this point a motion was put and carried that the Society take a recess for half an hour in order to hold a conference with a number of the leading architects who had been invited to attend and give their views upon the proposed legislation.

At the end of the recess the meeting was again called to order, and a motion was passed thanking the architects who had attended the conference, in response to our invitation, and inviting them to visit our rooms occasionally.

By resolution, action upon the act which was proposed was deferred.

Meeting adjourned at 10 P.M.

Gervais Lombard, *Secretary.*

June 4, 1900.—A special meeting of the Society was called to order at 8.20 P.M. by President Malochee, with the following members present: Messrs. Malochee, Theard, Ordway, Lawes, Llewellyn, Tutwiler, Zander, Wright, Coleman, Hyatt, Benson and Armstrong.

In the absence of Secretary Lombard, Mr. Coleman acted as Secretary. The object of the meeting was to receive and act upon the report of the Conference Committee on Legislation. Mr. Coleman was Chairman of the committee, and reported that it would be impossible to draft an act on which both the engineers and the architects would agree, and that the architects had volunteered, in consideration of the elimination by this Society of all reference to architects and architecture, not to go before the Legislature until the next session. The committee therefore recommended that their proposition be

accepted. Mr. Wright moved that the report be received, and its recommendation be adopted. Seconded by Mr. Hyatt, and unanimously carried.

The act was then carefully gone over and amended so as to leave out any reference to the architects or architecture, and also to change the length of time an engineer or surveyor must have practiced before the passage of the act, from *three* to *one* year, in order to be exempt from examination by proposed Board of Examiners. By motion duly seconded, the act as amended was indorsed by the Society, and laid over till the next meeting of the Society for the second and final indorsement. Adjourned.

GERVAIS LOMBARD, *Secretary*.

THE regular monthly meeting of the Society was called to order on Monday, June 11, 1900, at 8.15 P.M., by President Malochee, with seventeen members and one guest present.

The minutes of the last regular monthly meeting, and of the special meeting of the Society on June 4, were read and approved. The minutes of the special meeting of the Board of Direction on May 30, and of its regular monthly meeting on June 9, were read for the information of the Society.

The reports of the Secretary and of the Treasurer were read and approved. The Chairman of the Library Committee reported verbally that the back numbers of journals, magazines, etc., had arrived from the binder, neatly bound in convenient volumes, which are now in place in the bookcases, and that the committee had decided to index the volumes, and adopt certain rules allowing the members to take bound volumes home for short periods. The committee also announced the donation by Mr. F. T. Llewellyn of three years' back numbers of the *Engineering News*. By motion, which was duly seconded and carried, the report of the Library Committee was received, and a vote of thanks extended to Mr. Llewellyn for his generous donation.

By motion the Board of Direction was instructed to look into the matter of giving an outing, and to report upon it at the next meeting of the Society. The action of the Board of Direction in replying to the Committee of the Engineers' Society of Western New York, stating that our Society favored a Congress of Engineers with an exhibit at the Pan-American Exposition to be held in Buffalo, N. Y., in 1901, was ratified and approved by the Society.

By motion the usual order of business was suspended, and instead of the technical exercises commencing within a half hour after convening, they were deferred until the other business of the meeting was transacted.

By motion, duly seconded and carried, the following change in the Constitution, which was submitted by Mr. Theard and favorably voted upon for the first time at the last meeting of the Society, was favorably voted upon for the second and final time:

"To Article II, Section 3, add: 'He can be transferred to the grade of member when qualified to become so under Section 2 of this article.'"

Mr. Coleman moved that the Society indorse for the second and final time the proposed act regulating the practice of engineering and surveying, which was amended and favorably voted upon at the last meeting of the Society. Seconded by Mr. Theard and unanimously carried.

It was moved and carried that the act thus indorsed be referred back to the Legislative Committee with full power to urge its adoption by the Louisiana State Legislature, now in session, but with the understanding that

no expense be incurred without first obtaining the sanction of the Board of Direction. By motion, however, the Society authorized the committee to reprint the act as amended, at the expense of the Society, provided said committee deemed it necessary to do so.

President Malochee was authorized to answer Mr. Toledano's letter, and to assure the architects that we would not try to include them in our act this session, and in return for their assistance this session we would assist them, as far as possible, when they presented their act at the next session of the Legislature.

Mr. Theard notified the Society in writing of his intention to bring up the following proposed change to the Constitution, to be voted upon at the next meeting of the Society:

"Article II, Section 1. The members of this Society shall be designated as members, associate members and junior members. Members alone shall have the right to hold office."

"Article VIII. All the rights of the Society shall be common to all the grades of membership except that of holding office, which shall be confined to members."

By motion it was decided to take a recess until such time as Captain Hardee would be able to read his paper, as he was unavoidably absent.

GERVAIS LOMBARD, *Secretary.*

THE regular monthly meeting of the Society was called to order by President Malochee on Monday, July 9, 1900, at 8.10 P.M., with eighteen members and one guest present. In the absence of Secretary Lombard, Mr. J. F. Coleman acted as Secretary.

The minutes of the last meeting of the Society were read and approved. The minutes of the regular meeting of the Board of Direction were also read for the information of the Society.

Chairman Theard, of the House Committee, stated that before he went any further with his investigations in regard to suitable quarters for the Society, when our present lease expired, he would like to have some suggestions from the members of the Society.

The report of the Library Committee, which had been submitted to the Board of Direction, was read in detail, and the action of the Board of Direction was called to the attention of the Society. The fines which were suggested in the rules governing the library were by motion eliminated, and the rules so amended were adopted by the Society. (See report of Library Committee on file.) Mr. Theard's report upon the reprinting of the charter and By-laws was referred to the Board of Direction, said board to report back.

Mr. Theard's proposed amendment to the Constitution which would give associate members the right to vote, but not to hold office, was taken up, and when voted upon was lost.

Mr. James C. Haugh was absent from the city, but his paper upon "Pile Driving and Creosoting in Connection with the Construction and Maintenance of the Trestle and Bridge Built by the N. E. R. R. Co. across Lake Pontchartrain" was read by the Secretary. By motion a vote of thanks was extended to Mr. Haugh, and discussion was postponed until the next meeting, when it was hoped that Mr. Haugh would be present. Mr. F. T. Llewellyn then spoke interestingly of his recent trip to Mexico. He was given a vote of thanks by the Society.

Meeting adjourned at 10.10 P.M. GERVAIS LOMBARD, *Secretary.*

Engineers' Club of St. Louis.

510TH MEETING, JUNE 13, 1900.—The meeting was called to order at 8.30 P.M. As neither President nor Vice-President was present, Mr. Edw. Flad was chosen to preside. Twelve members and four visitors were present. The minutes of the 509th meeting were read and approved.

The first paper of the evening was presented by Mr. Nils Johnson, on the "Duty Tests of High-Service Pumping Engines No. 9 and No. 10, St. Louis Water Works." A detailed description was given of the method adopted for making the official duty tests of the two 15,000,000-gallon triple-expansion pumping engines designed and built by the Edw. P. Allis Company, of Milwaukee, for the St. Louis Water Works. The contract rating of the engines called for a duty of 135,000,000 foot pounds per 1000 pounds of dry steam on a running test of twenty-four hours. A forfeiture by the makers is provided for in case of failure of either engine to perform the specified duty, at the rate of $2000 per 1,000,000 foot pounds per 1000 pounds of steam. In case either engine exceeded the duty as per agreement, the maker was to be entitled to a bonus as reward for the superior efficiency of the engine, an amount to be in the ratio of $1000 for each 1,000,000 foot pounds in excess of 135,000,000. In the duty test of twenty-four hours' duration, each engine surpassed the contract rating by over 40,000,000 foot pounds, earning a total bonus of about $85,000 for the builders.

The average rate of dry steam per 1 horse power per hour was 10.7.

The results of the above tests indicate the highest efficiencies thus far obtained with large pumping engines. These engines are located at the Baden High-Service Pumping Station. They hold the distinction of being record breakers. A number of slides were shown illustrating the apparatus and general scheme adopted in the tests. A number of tables were also shown, giving results and data of the engines. The discussion was participated in by Messrs. Flad, Russell, Freeman and Bausch.

The second paper of the evening was on "Tests for Elastic Properties and Ultimate Strength of Concrete," by W. H. Henby. Some original laboratory investigations were made of the elastic properties and ultimate strength of stone and cinder concrete in compression and tension under various conditions. The results of a number of these tests were presented. The discussion was participated in by Messrs. Russell and Johnson.

The meeting adjourned to an adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., MAY 16, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President Alexis H. French in the chair. Sixty-five members and visitors present.

The record of the last meeting was read and approved.

Mr. William C. Ewing was elected a member of the Society.

The thanks of the Society were voted to Rear Admiral W. T. Sampson, to Mr. Frank O. Maxson and Mr. J. W. G. Walker, civil engineers U. S. N., and to Commanders John E. Pillsbury and J. G. Eaton, U. S. N., for courtesies extended to members of the Society on the occasion of the visit to the Navy Yard at Charlestown on the 16th inst.

The Secretary read a series of resolutions which had been received from the Canadian Society of Civil Engineers expressing their sincere appreciation of the hospitality shown to them on the occasion of their visit to Boston. The resolutions were beautifully engrossed on parchment in colors.

The President then introduced Prof. Louis Derr, of the Massachusetts Institute of Technology, who read a paper, entitled "Automobile Vehicles." The paper was very fully illustrated by lantern views.

In the discussion which followed the reading of the paper, Mr. Knight Neftel, of the New England Electric Vehicle Transportation Company, Mr. J. B. Blood, Mr. G. S. Curtis and Prof. Derr took part.

On motion of Mr. Hodgdon, the thanks of the Society were voted to Professor Derr for his interesting and instructive paper.

Adjourned. S. E. TINKHAM, *Secretary.*

BOSTON, MASS., JUNE 20, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M.; President Alexis H. French in the chair. Forty-five members and visitors present.

The record of the last meeting was read and approved.

Mr. Andrew M. Lovis was elected a member of the Society.

The Secretary read a communication from a committee of the Engineers' Society of Western New York in relation to the Pan-American Exposition, to be held in Buffalo from May to November, 1901, suggesting that it would be a most favorable opportunity to gather an engineering exhibit, and for the holding of a joint engineering congress or for each Society to hold its annual convention in that city during the Exposition. It also asked for an expression of opinion of this Society upon the matter. On motion the matter was referred to the Board of Government with full powers.

The President announced the death of John C. Haskell, a member of the Society, which occurred on June 12, 1900. On motion the President was requested to appoint a committee to prepare a memoir. The President has named as this committee Messrs. I. K. Harris and E. F. Dwelley.

Mr. Morris Knowles gave a very interesting account of the filtration experiments made at Pittsburg. The description was fully illustrated by lantern views.

Adjourned. S. E. TINKHAM, *Secretary.*

Civil Engineers' Club of Cleveland.

REGULAR MEETING, JUNE 12, 1900.—Called to order at 8.15 P.M. by President Hopkinson. Present, twenty-one members and six visitors. Messrs. E. E. Boalt, F. C. Osborn and H. C. Thompson appointed Reception Committee *pro tem.* Messrs. E. B. Wight and C. A. Palmer appointed tellers to canvass ballots for John T. Bever, Charles H. Davis, Andrew W. Foote, Harold H. Hill, Edward Horner, J. Verne Stanford and Wm. A. Stinchcomb, who were elected to active membership.

The names of Charles A. Cadwell and William C. Clark were proposed for active membership.

Letter from the Engineering Society of Western New York was read, asking for a committee from this Club to assist in making plans for an engineering exhibit at Pan-American Exposition. Prof. C. H. Benjamin

moved a committee of three be appointed for this purpose. Seconded by Mr. E. E. Boalt and carried. Messrs. Augustus Mordecai, A. H. Porter and M. E. Rawson were appointed.

It was moved and carried that this Club, in company with the other technical clubs, have an outing, details to be left with the House Committee.

The paper of the evening, entitled "The Inidikil System, or a Decimal System of Weights and Measures for the English-Speaking People," was read by Mr. A. Lincoln Hyde, member of the Club.

Discussed by Messrs. William H. Searles, C. O. Palmer, C. H. Benjamin, C. W. Hopkinson, A. Lincoln Hyde, E. E. Boalt, Ludwig Herman and F. C. Osborn.

Moved by Mr. Robert Hoffman, Mr. Ludwig Herman second, that the Club adjourn to the semi-monthly meeting June 26, to discuss the questions in the Question Box. Carried.

Adjourned at 10 P.M. to lunch served in Club rooms.

ARTHUR A. SKEELS, *Secretary.*

SEMI-MONTHLY MEETING called to order 8.15 P.M. of June 26; President Hopkinson in chair. Present, nine members and three visitors.

Mr. C. O. Palmer opened the discussion on the following questions from the Question Box:

1. In what respects do the trusts benefit the public; in what respects are they detrimental to the public; and do the benefits outweigh the detriments?

2. In what respects do the trusts benefit the workingman; in what respects are they detrimental to the workingman; and do the benefits outweigh the detriments?

Discussion followed by Messrs. C. W. Hopkinson, A. Lincoln Hyde, Ludwig Herman, Lucian Rust and A. A. Skeels.

Mr. Ludwig Herman moved a committee of two be appointed by the Chair to call upon our late President, Col. Jared A. Smith, and express the regret of the Club occasioned by his proposed removal from the city.

Seconded by Mr. A. Lincoln Hyde and carried.

The President appointed Messrs. Ludwig Herman and A. Lincoln Hyde.

Adjourned 10.15 P.M.

ARTHUR A. SKEELS, *Secretary.*

Association of Engineering Societies.

Vol. XXV. AUGUST, 1900. No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

San Francisco, Cal., August 3, 1900.—Regular meeting called to order at 8.30 p.m. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. W. W. Oates, architect, of Stockton, was elected to membership upon a count of ballot, and Mr. George Wright, architect, was proposed by G. W. Percy, A. Ballantyne and Otto von Geldern.

Mr. E. A. Rix read a paper entitled "Compressed Air Pumping," which was discussed at length.

The thanks of the Society were voted the author for his very comprehensive paper, and for his contribution to the literature on this important subject.

Adjourned. Otto von Geldern, *Secretary*.

Association of Engineering Societies.

Vol. XXV. **SEPTEMBER, 1900.** No. 3.

PROCEEDINGS.

Engineers' Society of Western New York.

September 4, 1900.—Meeting called to order at 8.15 p.m. The following members present: Messrs. Tutton, Diehl, Meyer, Knighton, Norton, Babcock, Lufkin, Sikes, Bardol, Tresise, Morse, and two visitors.

In the absence of the President, Mr. Tutton called the meeting to order.

It was voted that the minutes of the last regular meeting be approved as printed and circulated.

The report of the Pan-American Committee was left until the President arrived.

Mr. Lufkin was called to the chair, as Mr. Tutton was to address the Society.

Mr. Tutton.—I am to address you to-night on the reconstruction of the Kinzua viaduct.

As this bridge may be discussed before the American Society of Civil Engineers by the designers, I can give you but a brief description of the new mode of erection, etc.

The Kinzua viaduct, as most of you are aware, is in McKean county, Pa., and crosses Kinzua Creek and the Kushequa Railroad on the Bradford Division of the Erie Railroad. It is about sixteen miles south of Bradford and three miles north of Mount Jewett, and near Mt. Alton. The B., R. and P. R. R. runs around the end of this ravine not many miles to the north, I should say about five or six miles.

The old viaduct tablet, built in the masonry at the west or Mount Jewett end, reads as follows:

General Thomas L. Kane, President.
Robert Harris, Vice-President.
Octave Chanute, Chief Engineer.
Charles Pugsley, Principal Assistant.
C. H. Keefer and William Seaman, Assistants.
Located and designed by O. W. Barnes and A. Bonzano.
Masonry built by John C. Noakes.
Iron work built by Phœnix Bridge Company.

I understand the bridge was built by the Phœnix Bridge Company under the specifications of the Erie Railroad as they existed at that time; that is, in 1882. The Phœnix columns used were 9 inches in diameter.

The erection of the iron work was started about April 12, 1882, and I am a little in doubt about the date of completion. One tells me it was September 27; another that it was completed in October; and another that it was sometime in November of the same year.

The viaduct, as built, consists of two end spans 62 feet each, 19 clear spans, 61 feet each; 20 tower spans, 38 feet 6 inches, making the total length 2053 feet; maximum height, 301 feet. The old girders were uniformly 6 feet deep.

This structure is being replaced by the Elmira Bridge Company, with Grattan & Jennings as sub-contractors for erection.

The new lattice columns run about 2 by 3 feet. The new girders on the towers are 5 feet deep and on the clear spans 6 feet 7½ inches deep.

The work of tearing down the old structure commenced on May 20, 1900, when our first traveler was run out, and to-day we are working on the replacement of the last tower, and expect to complete the work this week, except a small amount of riveting.

The amount of iron in the old bridge was about 1500 tons, and in the new bridge approximately 3600, which will enable you to judge of their relative strength.

Both are single-track bridges.

The travelers and mode of construction were the result of studies of Mr. Gilman, superintendent of erection for Grattan & Jennings, and myself.

It will be noticed that the travelers are little more than a Howe truss bridge, without a bottom, whose width is 11 feet, and whose load is all carried on the top, at which place, also, the bracing is made. It is also furnished with suspended sidewalks for the safety of the men employed.

(Mr. Tutton showed a number of photographs of the new mode of erection, together with tracing of the travelers, which were explained by him to the Society, as also was the unloading device, by means of which the iron was taken from the cars and piled where desired.)

The length of the travelers is 176 feet.

They are mounted on double trucks at each end, and after being moved they are held in position by being simply jacked up and held by blocks.

The design of this viaduct is quite different from previous practice, and may call forth criticism on the part of bridge engineers on account of its lack of wind bracing.

The Elmira Bridge Company designed the bridge; that is, I understand, it is their design, they having submitted several designs to Chief Engineer C. W. Buchholz for his approval. The towers are braced longitudinally; there is no transverse bracing other than what you might call portal bracing.

The masonry has all been repaired, and most of it was in good shape.

I was very glad the sidewalks were in place when I had occasion to go out on the bridge.

Mr. Knighton.—How is the spreading of the tower posts accomplished without the use of spreaders?

Mr. Tutton.—When the beams are suspended it takes but little force to pull them to position, the rope being flexible and long enough to act like a pendulum. We designed and built an apparatus that we called a spreader, but found we had no occasion to use it.

The batter is 2 inches per foot.

The old structure was theoretically safe under the specifications in use at that time, but the weights of cars and engines have changed materially since.

Under the present conditions it would not be considered safe, although I do not mean to imply that the structure would now be unsafe except for the fact of the great increase in trainloads and engine weights.

We use compresssed air for the riveting. We are not doing the painting.

It was moved and seconded that a vote of thanks of the Society be extended to Mr. Tutton for his very interesting and instructive address. Carried unanimously.

Mr. Diehl.—Mr. President, Mr. Bardol, who was appointed a member of the Pan-American Committee in place of Mr. Lufkin, who resigned, was present at the meeting this morning of the Committee of the American Society of Civil Engineers and the Pan-American Committee of this Society, and I would ask that Mr. Bardol be called upon to tell us about the meeting.

Mr. Bardol.—We did not do very much. At 10 o'clock Mr. Haven telephoned, asking if I could attend the meeting. When I got there I found Major Symons and Mr. Haven, of this Society, and Mr. Noble, Chairman, Professor Ricketts, Mr. Cartright, Mr. Seamans and Mr. Wisner, the Committee of the American Society of Civil Engineers on the Pan-American Exposition.

Major Symons acted as our spokesman, and explained his views. He stated that he would like to have the co-operation of the American Society and other societies to bring about an engineering exhibit next year. The question of expense was taken up, and the gentlemen from the American Society asked where the necessary money was coming from. Major Symons stated that he had talked with Mr. Buchanan, and thought it would not be difficult to get sufficient money to see us through. The gentlemen of the American Society agreed with the suggestion of Mr. Buchanan that it was necessary to obtain a competent manager to take charge of the exhibit, and to get other societies to co-operate with us.

We took the big automobile and inspected the Pan-American grounds, etc. The gentlemen were very much impressed with the size of the undertaking, and they came back and held a meeting in the afternoon.

Mr. Diehl.—Was anything said about a congress?

Mr. Bardol.—They spoke about that, but thought it was not practical. It is intended simply to have an engineering exhibit with some prominent engineer in charge.

They spoke about establishing headquarters to entertain visiting engineers.

Mr. Lufkin.—Was anything said about getting engineering societies to hold their conventions here next year?

Mr. Bardol.—No, sir. Something was said about having an American Society Day, but nothing was said about a convention.

The American Society of Municipal Improvements, which is composed largely of engineers of cities, is to hold its convention at Niagara Falls next year. This will arouse some interest.

Mr. Meyer.—What is meant by an engineering exhibit?

Mr. Bardol.—To have drawings and models. They have models of American cities at the Paris Exposition. Boston and New York furnished very elaborate exhibits.

Major Wheeler also attended the meeting, and went out to the grounds with us. He was asked how much space could be obtained, and he said he thought 40 x 100 feet would be large. Unfortunately Mr. Buchanan is out of town, so nothing official was done, but it is certain the Pan-American

Company would do something toward defraying the expense. The gentlemen from the American Society did not think the Society should be called upon to pay any of the expense.

Mr. Tresise.—An article in *Engineering News* a couple of weeks ago stated that an informal ballot was taken by the American Society in London, for the place of their convention for 1901, and that Buffalo received the greatest number of votes.

Mr. Diehl.—At this meeting we were to have several reports of committees, and the President had arranged to have the printed copies of the new Constitution ready at this meeting. Mr. Haven was taken ill to-day, and, in view of this fact, the reports will have to be delayed until the next meeting.

Meeting adjourned at 9 p.m. G. C. Diehl, *Secretary.*

Louisiana Engineering Society.

The regular monthly meeting of the Society was called to order on Monday, August 13, 1900, at 8 p.m., by President Malochee, with seventeen members and one guest present.

The minutes of the last meeting of the Society were read and approved, and the minutes of the meetings of the Board of Direction held on July 14, July 28 and August 11 were read for the information of the Society.

The monthly statements of the Secretary and of the Treasurer were read and approved.

The House Committee submitted a written report showing progress, and asking to be authorized to continue investigations with full power to act. The report was received and its recommendations approved.

The Legislative Committee made a written report explaining why the proposed "act regulating the practice of engineering and surveying" had failed to pass the State Legislature. The report was received.

The Committee upon Revision of the City Building Laws made a verbal report of progress. Received.

Mr. Theard made a verbal report of progress upon the preparation of the Charter and By-laws for reprint. Received.

The recommendation of the Board of Direction in regard to the Society giving an "outing" to Avery's Salt Mines in the latter part of September or early part of October was approved.

At this point the President announced that the half hour of routine business must now be followed by the technical exercises, after which the routine business could be resumed.

Mr. James C. Haugh's paper upon "Pile-Driving and Creosoting," which had been read at the last meeting of the Society, was taken up for discussion. Pile-driving was a familiar subject to most of those present, and a long and unusually interesting discussion followed.

Mr. W. B. Wright had, at the request of the President, prepared a statement of his experience with pile-driving, and the paper he read was quite interesting. During the discussion Mr. Hazlehurst gave his experience with pile-driving in Algiers for the stand pipe of the Algiers Water Works Company, together with some useful formulas for obtaining the bearing power of piles in alluvial soil.

Major Harrod gave some useful information in regard to the foundations of the Custom House Building, together with statistics of its subsequent settlement.

New business was taken up and a motion was passed authorizing the reprint of the Charter and By-laws provided it did not cost more than $32.

The following resolution was put and carried:

Resolved, That the Louisiana Engineering Society does hereby extend to the Hon. Loys Charbonnet its hearty thanks for his assistance, and further tender of assistance, in the matter of the proposed act to regulate the practice of engineering in the State of Louisiana; further

Resolved, That the Secretary be instructed to transmit a copy of these resolutions to the Hon. Loys Charbonnet.

A motion was passed authorizing a committee of five members to be appointed by the President as an "Arrangement Committee" for the proposed "outing." President Malochee later appointed the following members to the committee: Messrs. F. M. Keer, Chairman; James C. Haugh, Jules Godchaux, J. J. Frawley and Ben. Andrews, Jr.

The meeting adjourned at 10.15 P.M.

GERVAIS LOMBARD, *Secretary.*

NEW ORLEANS, SEPTEMBER 20, 1900.—The regular meeting of the Society was called to order by President Malochee, at 8 P.M. on Monday, September 10, with eighteen members and one guest present.

The minutes of the last meeting of the Society were read and approved, and the minutes of the Board of Direction meetings held on August 18, August 30 and September 8 were read for the information of the Society.

It was moved and carried that the report of the Board of Direction be approved.

Chairman Kerr, of the Committee of Arrangements for the "outing," made a verbal report to the effect that steps had been taken looking toward the necessary arrangements, investigations, etc. So far no satisfactory arrangement had been made with the S. P. R. R. Co., but the committee was still in communication with the said railroad company, and expected to hear from them shortly. Basing the cost of the train and transportation upon the figures obtained about this time last year,—that is $350,—the committee estimates that with three hundred guests the total cost will amount to about $650, and the committee therefore recommends that the tickets be sold to the members of the Society at $1.50 each. This would leave a balance of about $200 to be met by the Society. The committee further recommended that, in order to properly boom the "outing" and make it a success, President Malochee be authorized to appoint, as soon as possible, several committees as follows: A Committee on Finance, a Committee on Refreshments, a Press Committee and a Train Committee. He stated that the above estimate included a substantial meal and light refreshments. By motion, the report was received and its recommendations approved, and the Arrangement Committee, together with the Board of Direction, was given full power to act, it being understood that care be exercised, as the matter was one which required careful handling.

At this point President Malochee was excused on account of a business engagement, and Vice-President Theard assumed the chairmanship.

As Messrs. Hardee, Bell and Brow were all three absent, the discussion upon the New Orleans building laws was deferred.

The Chair announced that at our next meeting Mr. W. M. White would read a paper upon "Water Measurement of a Centrifugal Pump Test at Jourdan Avenue Drainage Station."

The Secretary was instructed to write to Mr. Klorer and request him to give his consent to being transferred to full membership, as he was eligible.

Meeting adjourned at 8.50 P.M.

GERVAIS LOMBARD, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., SEPTEMBER 19, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock P.M., President Alexis H. French in the chair; sixty-six members and visitors present.

The record of the last meeting was read and approved.

Mr. Charles C. Whittier was elected a member of the Society.

The thanks of the Society were voted to the Fore River Engine Works for courtesies extended on the occasion of the visit to its works on July 18, 1900; also to the New Bedford Water Board for courtesies extended on the occasion of the visit to the pumping station and reservoir of the New Bedford Water Works, on August 22, 1900. The thanks of the Society were also voted to the Rockport Granite Company, to Cape Ann Granite Company and to the Pigeon Hill Granite Company for courtesies extended to-day while visiting the granite quarries of these companies at Cape Ann.

The President announced the death of Moses W. Oliver, one of the oldest members of the Society, which occurred on September 8, 1900, and by vote of the Society the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. R. A. Hale and A. D. Marble.

The literary exercises of the evening were opened by Mr. Henry Manley with an account of the annual convention of the American Society of Civil Engineers held at London in July last. Mr. Edward Sawyer followed, giving some of the impressions left in his mind from a trip abroad the past summer. Mr. F. W. Hodgdon gave a very interesting description of some of the docks in England visited by him, and Mr. H. D. Woods spoke of some special features of interest at the Paris Exposition. Mr. Desmond FitzGerald concluded the exercises with some remarks on places visited by him during the summer.

Adjourned. S. E. TINKHAM, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, SEPTEMBER 7, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved. A communication was read from the editor of the *Mining and Scientific Press,* requesting that the Society permit him to publish Mr. Dana Harmon's paper on "Stamp Milling," to be read this evening. The Secretary was instructed

to communicate with the editor, stating that there would be no objection to the publication of the paper after its appearance in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and that he would be notified in due time.

Mr. George A. Wright, an architect, was elected to membership by ballot. Mr. Dana Harmon read a paper entitled "Stamp Milling of Free Gold Ores," which was discussed.

After expressing the thanks of the Society to Mr. Harmon for the valuable contribution to the Society's transactions the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies.

Vol. XXV. OCTOBER, 1900. No. 4.

PROCEEDINGS.

Engineers' Society of Western New York.

Regular Meeting, October 2, 1900, at 8.15 p.m.—Mr. Haven, President, in the chair.

The following members were present: Messrs. Haven, Diehl, Sikes, March, Knighton, Wilson, Cornell, Whitford, Buttolph, Kielland, Powell, Fell, Bassett and Norton.

The minutes of the last regular meeting were approved as printed.

The Executive Board reported that at the meeting of July 16 they found that the ballots were almost unanimously in favor of the proposed amendments to the Constitution and By-laws, and that they were declared adopted; also that a majority of the votes for regular meeting night were for Tuesday; also that the President was ordered to contract for printing 500 copies of Constitution and By-laws, as amended, which he has done.

The Treasurer reported that there was $30.88 in the treasury, and that he had in hand bills amounting to $49 awaiting payment.

The Secretary reported that there were twelve members who had not paid their dues for the current year.

The application for membership of Mr. Alonzo H. Watson was received. The President said that it had been approved by the Executive Board. The application was ordered submitted to a letter ballot.

The President reported that the Society had elected as members Mr. George Frederick Morse and Mr. Charles Henry Davis, and as associate Dr. Truman J. Martin.

The President called for a report of the Special Committee on Membership.

Mr. Buttolph, one of the committee, said that the Chairman of that committee had never called a meeting, therefore he did not know that anything had been done. The President said that he supposed that the object of committees of more than one person was that every member would do something and not leave everything to the person first named.

After some talk Mr. Buttolph moved that that committee be discharged and another of five members be appointed. Seconded by Mr. March, and so voted.

The President appointed Messrs. Buttolph (Chairman), Sikes, Cornell, Knighton and Wilson a committee to take immediate measures to increase our membership.

The Executive Board was authorized to have printed 500 blank applications for membership and other forms to conform to amended Constitution and By-laws.

The Librarian made a report on various things connected with the library, and after a full discussion it was unanimously voted that "When there is money enough available in the treasury, the Librarian shall be authorized to procure the *Engineering Index* for the years 1884 to 1899."

The Committee on Pan-American Engineering Exhibit reported informally that they were in correspondence with several gentlemen with a view of recommending one or more of them to the Director-General of the Pan-American Exposition Company as suitable persons to take charge of the matter.

The President was directed to appoint a committee of three on the program for the annual meeting. and he appointed Messrs. Wilson, Cornell and Speyer. (Mr. Wilson declined to act, and the President appointed Mr. Geo. M. Busch.) This committee is ordered to report progress at the November meeting.

The President read the papers in the "Topic Box" and requested members to talk on any of them.

Mr. March said, in reply to the President, that he would at the annual meeting talk on paving brick tests.

Meeting adjourned at 9.30 P.M. G. C. DIEHL, *Secretary*.

Technical Society of the Pacific Coast.

REGULAR MEETING, October 5, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. Geo. W. Dickie addressed the Society, and related informally the experiences and observations of his recent journey to Europe, where he attended the meetings of the American Society of Mechanical Engineers and the American Society of Civil Engineers, in London, and visited the Paris Exposition.

Adjourned.

OTTO VON GELDERN, *Secretary*.

Louisiana Engineering Society.

PRESIDENT MALOCHEE called the meeting to order on Monday, October 8, at 8 P.M., with twenty-three members and two guests present.

The minutes of the last regular meeting of the Society were read and approved. The minutes of the regular meeting of the Board of Direction, held on October 6, were read for the information of the Society.

The reports of the Secretary and of the Treasurer were read and approved. They showed a balance in bank to date of $406.02.

The Chairman of the Library Committee reported verbally that twelve more volumes of back numbers had arrived from the bookbinder, and that the pamphlets from the U. S. Geological Survey, for which he had written, had also arrived. The record book was reported on the shelf,

and any member desiring to carry books home could now do so by receipting for them in the record book.

The Chairman of the Outing Committee, Mr. Kerr, made a verbal report to the effect that all arrangements for the outing to Avery Salt Mines on Saturday next had been satisfactorily completed, and that the outing was already an assured success. He was glad to report that the total cost was to be within the amount estimated at the last meeting,—namely, $650. This report was supplemented by that of Chairman S. F. Lewis, of the Finance Committee, who stated that so far the tickets sold amounted to about $350. Mr. DeBuys, the Chairman of the Refreshment Committee, stated that he had contracted for all the refreshments needed, and that, besides light refreshments served on the train going and coming, a substantial noonday meal would be served in a new assembly hall at the mines.

President Malochee announced that Mr. A. M. Lockett would read a paper at the November meeting upon the subject of "Condensers."

The Secretary was instructed to send each member of the Society a copy of the Constitution and By-laws, and to also send one to each of the Societies forming the Association of Engineering Societies.

Under the head of Technical Exercises Mr. W. M. White read a paper upon "Water Measurement of a Centrifugal Pump Test at Jourdan Avenue Drainage Station." Great interest was manifested, and after the discussion a vote of thanks was passed expressing to Mr. White the sincere appreciation the Society felt for his most interesting paper. Mr. J. F. Coleman was announced as Chairman of the Train Committee for the outing, said committee to consist of twenty-four members.

The meeting adjourned at 9.45 P.M.

GERVAIS LOMBARD, *Secretary.*

Montana Society of Engineers.

REGULAR MEETING, October 13, 1900.—Meeting was called to order by President Blackford at 8.30 P.M., with the following members present: Harper, Christian, R. R. Vail, Moore, Sickles, Macdonald, Page, Dunshee and McArthur, and two visitors, Messrs. North and Ingersoll. The minutes of the last meeting were read and approved.

The application of Mr. Charles H. Davis was read and, after discussion, the By-law of the Society with reference to the indorsement of the application of at least two members was waived by unanimous consent and the Secretary instructed to send out the usual letter ballot. The Secretary was instructed to purchase a blackboard for the Society.

This completing the business before the meeting, the President introduced Mr. E. C. Sickles, of Anaconda, who read a paper on "The Compression of Air." The speaker took up the single-phase and double-phase type of air compressors and discussed quite fully the relative advantages and efficiency of each, illustrating his remarks by many sketches and drawings.

The paper brought out an interesting discussion from the members, in which Messrs. Blackford, Christian, Harper and Page took part.

Adjourned.

R. A. MCARTHUR, *Secretary.*


DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
BUFFALO
BOSTON
CLEVELAND
CINCINNATI
ST. LOUIS
SAN FRANCISCO
LOUISIANA
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

Vol. XXV. NOVEMBER, 1900. No. 5.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., October 17, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.45 o'clock p.m., President Alexis H. French in the chair; ninety-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Charles H. Davis and Alfred T. Tomlinson were elected members of the Society.

Mr. Frederick Brooks, for himself and Mr. Wm. B. Fuller, a committee appointed to prepare a memoir of Mr. John H. Blake, submitted and read its report.

Mr. Robert S. Hale then read the first paper of the evening, entitled "A Successful Siphon."

In the absence of the author, the Secretary read a paper by Mr. William D. Bullock, entitled "Description of Experiments on Brick and Concrete Arches."

Mr. Frederic H. Fay read a paper describing some tests made by the Engineering Department of Boston on "The Strength of a Rapp Floor and of a Gustavino Arch Floor." The rest of the evening was devoted to accounts of several of the systems of concrete floor and arch construction, which were liberally illustrated by lantern views. Mr. William M. Bailey spoke of expanded metal in connection with concrete construction. Mr. M. C. Tuttle described the Ransome system of concrete work, and Mr. A. W. Woodman the Roebling system.

After passing votes of thanks to Messrs. Bailey, Tuttle and Woodman, the Society adjourned.

S. E. Tinkham, *Secretary.*

Boston, Mass., November 21, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.40 o'clock p.m., President Alexis H. French in the chair; fifty-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Roy C. Aiken and Alfred M. Wyman were elected members of the Society.

The Secretary read a communication from the Chairman of the Board of Managers of the Association of Engineering Societies extending an invitation

to the members of this Society to discuss any of the papers published in the JOURNAL; discussions to be forwarded to the Secretary of the Association not later than three months from the date of publication of the number in which the paper appears. Authors of papers will be allowed to close the discussion, if desired, in a subsequent issue not over two months later.

On motion of Mr. Hodgdon, it was voted that the thanks of the Society be extended to the officers of the Boston Elevated Railway Company for courtesies extended at this afternoon's excursion.

Mr. William O. Webber read the paper of the evening, entitled "The Use of Water Powers by Direct Air Compression." The paper was illustrated by numerous lantern views. After a discussion in which Messrs. R. A. Hale, Blood, Coffin, Porter and Webber took part, the Society adjourned.

S. E. TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

511TH MEETING, ST. LOUIS, SEPTEMBER 19, 1900.—The meeting was called to order at 8.20 P.M., President Chaplin in the chair; nineteen members and nine visitors were present. The minutes of the 510th meeting were read and approved. The report of the 295th meeting of the Executive Committee was read. The applications for membership of Charles Henry Davis, Hugo Frederick Urbaner, Charles H. Tucker and Duncan F. Cameron were presented to the Club.

The paper of the evening, on "The Electrical Features of the Paris Exposition," was presented by Prof. H. B. Shaw, of the State University of Columbia. Although Professor Shaw did not attend the exposition, he reviewed, in a most interesting manner, the important electrical features connected with the exposition, accounts of which appeared in various technical journals. A general description was given of the exposition grounds. The moving sidewalk, operated by two large motors, was compared with the one at the Chicago World's Fair. The motors were each 850 horse power, the largest ever built. The third-rail road and a number of foreign constructions of engines and generators were described.

The meeting adjourned to the neighboring room, where a light lunch was served.

F. E. BAUSCH, *Secretary.*

512TH MEETING, ST. LOUIS, OCTOBER 3, 1900.—The meeting was called to order at 8.15 P.M., with President Chaplin in the chair; thirty-seven members and six visitors were present. The minutes of the 511th meeting were read and approved. The minutes of the 296th meeting of the Executive Committee were read.

The names of Messrs. Charles H. Tucker, Charles Henry Davis, Hugo Frederick Urbaner and Duncan F. Cameron having been recommended by the Executive Committee, they were balloted for and declared duly elected members of the Club.

The Committee on Club Quarters made a report without recommendation. It was moved and seconded, and the motion carried, that the Executive Committee arrange for another evening at the Office Men's Club before making a final decision upon the offer proposed to the Engineers' Club.

Mr. J. A. Ockerson made a report upon his duties as delegate from this Club to the meetings of the Society of Civil Engineers of France.

The paper of the evening, on "The Paris Exposition of 1900," was presented by Mr. J. A. Ockerson. A general description was given of the grounds, buildings and distribution of exhibits, alluding also to the tramways of Paris and transportation facilities. A comparison was made between the Paris Exposition and the Chicago World's Fair, the essential difference between the two being the greatly scattered condition of the buildings and departments of the former as compared with the plan of concentration and architectural effect of the latter. Mr. Ockerson exhibited some excellent slides, and presented maps showing location of exhibits at the World's Fair.

The meeting adjourned to an adjoining room, where a light lunch was served. F. E. Bausch, *Secretary.*

513th Meeting, St. Louis, October 17, 1900.—The meeting was called to order at 8.15 p.m., with President Chaplin in the chair; twenty-four members and four visitors were present. The minutes of the 512th meeting were read and approved. The minutes of the 297th meeting of the Executive Committee were read.

The application for membership of Gerard Swope having been recommended by the Executive Committee, he was balloted for and declared elected.

The paper of the evening was on "The Sewer System of St. Louis," presented by E. M. Hermann, Sewer Commissioner. The paper treated of the construction, maintenance, repairs, cleaning and general operation of the sewers of St. Louis. Mr. Hermann presented charts showing cross-sections of many of the larger sewers, the method of construction and materials used in the walls, etc. He also exhibited a collection of lantern slides giving views of the interiors of the sewers, showing peculiar construction in many places and the character of the breaks and fissures in the decaying walls of the old sewers that were caused by the giving way of walls undermined by the flow of sewage after the bottoms had been worn through. The subject was discussed by Messrs. Moore and Petzmann, and by Professors Van Ornum and Kinealy.

The meeting adjourned to the adjoining room, where lunch was served.

F. E. Bausch, *Secretary.*

Louisiana Engineering Society.

New Orleans, November 15, 1900.—The regular monthly meeting of the Society was called to order on Monday, November 12, 1900, at 8 p.m., by Vice-President Theard, with fourteen members and one guest present.

The minutes of the last meeting of the Society were read and approved. The minutes of the Board of Direction meeting, held on November 10, were read for the information of the Society. The reports of the Secretary and of the Treasurer were read and approved. They showed a balance on hand of $203.70.

Mr. Kerr, as Chairman of the Arrangement Committee for the "outing," submitted a final written report, which was received, and the committee relieved of further duty. The following resolutions were passed:

Resolved, That the thanks of the Louisiana Engineering Society are due and are hereby tendered the officials of the Southern Pacific Company for the elegant service, and the efficient, courteous train crew furnished for the "outing" to Avery's Island, on October 13, 1900.

Resolved, That the thanks of the Louisiana Engineering Society are due and are hereby tendered the Avery Island Rock Salt Mining Company for the courteous and generous reception accorded the Society on its outing on October 13, 1900, recognizing the extent to which the management incommoded itself and its officers and employes in furnishing the opportunity and means to descend into the mines and to inspect their magnificent plant, not to mention other personal courtesies during the course of a most enjoyable day.

Whereas, The outing to Avery's Island, given by the Louisiana Engineering Society, on October 13, 1900, has proved a complete success, affording to our members an interesting study of the resources of our State, and offering an agreeable recreation to our guests; and

Whereas, The success of the outing was conditional upon its proper management; be it

Resolved, That the thanks of the Louisiana Engineering Society are hereby tendered to the following gentlemen for the able and efficient manner in which they performed the duties assigned to them on that occasion: President H. J. Malochee; Chairman Kerr, of the Arrangement Committee; Chairman Lewis, of the Finance Committee; Chairman Perrilliat, of the Press Committee; Chairman DeBuys, of the Refreshment Committee; Chairman Coleman, of the Train Committee, and the several members of the respective committees.

The Secretary was ordered to spread the above resolutions upon the minutes, and to send copies to the proper parties.

A tabulated statement of the assets and the probable liabilities up to January 1, 1901, which had been prepared by the Secretary at the request of the Board of Direction, was read. It showed that the probable balance to the credit of the Society after all bills are paid will amount to about $435.

A motion was passed that the Society give a smoker similar to the one given last year. Said smoker to be given on the night of the December meeting, and not to cost more than $75.

The communication from Mr. James Ritchie relative to discussion of papers appearing in the Journal was read, and a committee of three, with Mr. Tutwiler as Chairman, and Messrs. W. M. White and Zander, members, was appointed to go over the grounds and decide what the best method of procedure would be, and to report back to the Society.

Mr. A. M. Locket stated in a communication that his prolonged absence from the city would prevent him from reading his paper at this meeting, but that he would not fail to read it at the December meeting.

The meeting adjourned.

Gervais Lombard, *Secretary.*

Engineers' Club of Cincinnati.

118th Regular Meeting, Cincinnati, Ohio, October 18, 1900.—Dinner was served at 6.30 p.m.

The regular meeting was called to order at 8 p.m.; President Punshon in the chair, and fifteen members present.

Minutes of the meeting of September 20 were read and approved.

On ballot being taken, Mr. Charles H. Davis, of New York city, was elected an active member.

The paper for the evening, by Col. Latham Anderson, on "Economy Attainable by the Use of the Hydraulic Giant in Making Extensive Cuts and

Fills in Clay or Gravel," was read by Mr. Elzner in the absence of the writer.

The paper comprised a discussion and description of various methods of excavating by hydraulics, with a special plea for the use of the hydraulic giant, with instances of work accomplished by it at comparatively small cost, concluding with a recommendation of this method for removing material from the hills west of Cincinnati for filling Mill Creek bottoms.

After some discussion of the subject and a vote of thanks to the writer of the paper the meeting adjourned.

J. F. WILSON, *Secretary.*

119TH REGULAR MEETING, CINCINNATI, OHIO, NOVEMBER 15, 1900.—Dinner was served at 6.25 P.M.

The regular meeting was called to order at 7.30 P.M.; with President Punshon in the chair and nineteen members present.

Minutes of the meeting of October 18 were read and approved.

Application for active membership, properly indorsed, was presented by James C. Hobart, secretary and manager the Triumph Electric and Ice Machine Company, of Cincinnati, Ohio.

The Secretary reported the death of Sherman E. Burke, which occurred accidentally at Dennison, Ohio, on October 17, while participating in an inspection trip over the lines of the Pennsylvania Railroad system, with which he was connected. On motion, the Chair appointed a committee, consisting of Messrs. James A. Lilly and J. A. Rabbe, to prepare a suitable resolution in respect to the deceased member.

The Secretary read a communication from Mr. Hugo Diemer, now a professor at the Michigan Agricultural College, in which he urged that the sentiments of the Club be expressed to the effect that the proposed establishment of a department of mechanical engineering at the University of Cincinnati be upon a basis on a par with the other scientific and classical departments. On motion, the same was laid on the table.

The paper for the evening, received from Mr. W. B. Ruggles, now Assistant Engineer of the Department of Western Cuba, entitled "Improvement of Matanzas Harbor," in which he described the various plans for the work, was read by Mr. L. E. Bogen. After the reading of the paper, Mr. Bogen exhibited a number of lantern slides from views illustrative of Cuban life and characteristic of that country, in which he was assisted by Mr. J. P. Horstman, who was assistant to Mr. Ruggles on the work, and who has recently returned from Cuba.

A vote of thanks was tendered Mr. Ruggles for his interesting paper, and to Messrs. Bogen and Horstman for the rendition of the same and the preparation, exhibition and description of the views.

On motion, adjourned.

J. F. WILSON, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, NOVEMBER 2, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

The Secretary read a letter from Mr. Trautwine, of the Association of Engineering Societies, suggesting certain changes in the wording of

the paper on the subject of "Stamp Milling of Free Gold Ores." Upon motion, this matter was referred to the Board of Directors, with the instructions that the paper be submitted to the Committee on Publication for suitable revision.

A resolution was read embodying a memoir on the late member, W. G. Curtis, which was ordered spread upon the minutes and copies sent to the nearest relatives of the deceased. Also ordered published in the JOURNAL OF ENGINEERING SOCIETIES as customary, with a half-tone photograph of the late member.

The Secretary reported the death of Fred. W. Wood, of Los Angeles, and was instructed to communicate with some of the Society's members in that locality for the purpose of obtaining a memoir.

The President appointed a committee consisting of Messrs. E. F. Haas, J. G. H. Wolf and Otto von Geldern to assort the unbound JOURNALS on file in the library, so as to get a certain number of them bound, and to report the probable expense of such work.

Mr. G. Alexander Wright read a paper on the subject of "Arbitration: Its Place in Our Professional Practice," which was discussed by Mr. E. J. Molera and Mr. George W. Dickie.

Meeting adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., NOVEMBER 5, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Present, ten members and six visitors; President Powell in the chair. Minutes of previous meeting read and approved.

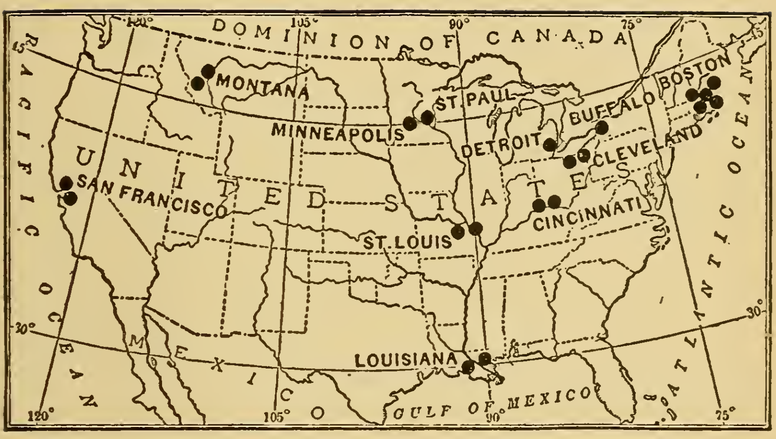
A rather informal and indefinite verbal proposition from the Commercial Club, touching the appointment of committees by that body and our own to confer on the advisability of closer relations between the two, was referred to the government of the Society for more definite development. The resignation of Mr. H. N. Elmer was accepted. A general invitation by Mr. James Ritchie, Chairman of the Board of Managers A. E. S., to discuss the published papers of the Association, was read.

No action was taken on communications from the Technical Agency of Newton, Mass., and from Mr. T. W. Hurst.

The application for membership, submitted by the Examining Board, of Mr. Charles H. Davis, of New York, was referred to a committee to examine and report on at the next regular meeting.

Mr. Oliver Crosby read a paper on "The Manufacture of Steel Castings by the Tropenas Process." He made special reference to the plant of the American Hoist and Derricks Company, and exhibited some striking and curious specimens of the steel, together with drawings, tables, etc.

C. L. ANNAN, *Secretary.*



DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
ST. PAUL
MINNEAPOLIS
DETROIT
BUFFALO
BOSTON
CLEVELAND
SAN FRANCISCO
ST. LOUIS
CINCINNATI
LOUISIANA
120°
105°
90°
75°
45°
30°

Association of Engineering Societies.

Vol. XXV. **December, 1900.** No. 6.

PROCEEDINGS.

Engineers' Society of Western New York.

The annual meeting of the Society was held in the Society rooms, 975 Ellicott Square, at 4.30 and 8.30 P.M., Tuesday, December 4, 1900. There were present Messrs. Haven, Kielland, Knighton, Tutton, Buttolph, Norton, Whitford, Weston, Bardol, Roberts, Speyer, Babcock, Powell, Knapp and Fell. Mr. Knighton was appointed Secretary *pro tem.* The minutes of the last regular meeting were approved as printed.

Reports of the Executive Board, the Secretary, Treasurer, Librarian and Representative on the Board of Engineering Societies were received and referred to the Executive Board.

Messrs. Buttolph and Kielland were appointed tellers to canvass the vote cast for officers of the Society for the ensuing year. They reported that the vote was unanimous, and thereupon the President declared that the following persons were elected:

President—William A. Haven.

Vice-President—George H. Norton.

Directors—T. Guilford Smith, for one year; Louis H. Knapp, for three years.

Secretary—George C. Diehl.

Treasurer—George R. Sikes.

Librarian—John A. Knighton.

Applications for membership were read as follows: For members—Jasper S. Youngs, Henry Clark, Horace P. Chamberlain, Frank L. Bapst, Henry Bartlett Alverson, Charles L. Boardman, John T. Herron, John J. Clahan, Eugene C. Hanavan. For associates—Emmett W. Huntington, Charles Mosier, Louis Marburg.

The Secretary was ordered to send out letter ballots for the above-named candidates.

On motion of Mr. Norton, it was voted that the President appoint a committee of one to report at the next meeting on the question of our Society joining the American Section of the International Association for Testing Materials.

Mr. March was appointed as such committee.

Mr. Bardol made an informal report for the Pan-American Committee, and after considerable discussion it was voted that the Committee on Pan-American Affairs be discharged.

Mr. Bardol moved the adoption of the following resolution:

That the Secretary be directed to write a letter to Mr. Selim H. Peabody, Superintendent of Liberal Arts of the Pan-American Exposition Company, and intimate to him that this Society will appoint a committee to co-operate with him or the Exposition Company in the matter of an Engineering Exhibit, if they desire to have such an exhibit, and to call attention to what has been done; to report at the next meeting.

Seconded by Mr. Norton, and carried unanimously.

The President thanked the Society for his re-election as President, and said that the Constitution provided that the outgoing President should make a report and address, but that, as at the present time there did not seem to be an outgoing President, no address had been prepared. He spoke on the general condition of the Society, and what, in his opinion, should be done for its welfare. He also promised that before the next meeting he would write his address in a more formal way and deliver it to the Society.

The President then presented to the Society a "Description of a Compleat Enginier," copied from a book written by David Papillon, Gent., published in London, in 1645, chapter first of which book is headed "Of the True Character of a Compleat Enginier." This chapter was copied verbatim, and the President said he would have it properly framed and hung up in the rooms of the Society. The Society received the gift with a vote of thanks to the President.

Adjourned at 11.55 P.M.

JOHN A. KNIGHTON, *Secretary pro tem.*

REPORT OF THE SECRETARY.

BUFFALO, N. Y., December 1, 1900.

W. A. HAVEN, ESQ., PRESIDENT ENGINEERS' SOC. OF WESTERN NEW YORK, BUFFALO, N. Y.

Dear Sir,—In compliance with Article I, Section 3, of the By-laws, I submit the following report:

Members—January 1, 1900, there were thirty-two members whose dues were paid; thirty-one members whose dues were unpaid; total, sixty-three.

During the past year sixteen members have been indefinitely suspended for non-payment of dues; one member has resigned; one honorary member has been elected; twelve new members have been elected; one associate has been elected; seven applications for membership are on hand.

December 1, 1900, there were fifty-six members whose dues were paid; six members whose dues were unpaid; total, sixty-two.

DUES.

Total amount received from members from December 21, 1899, to December 1, 1900:

Entrance fees	$70.00	
Dues	497.50	
Key deposits	3.25	
		$570.75
Amount deposited with Treasurer		570.75

MEETINGS OF THE SOCIETY.

Nine meetings of the Society have been held since January 1, 1900, with an average attendance of eighteen.

Eleven meetings of the Executive Board have been held since December 16, 1899, with an average attendance of five.

On July 7, 1900, through the courtesy of Major Thomas W. Symons, U. S. A., the Society visited the United States Government Breakwater and work connected therewith.

Respectfully submitted,

G. C. DIEHL, *Secretary.*

Condensed report of the Treasurer:

GENERAL FUND.

Cash on hand December 4, 1899	$138.89
Total received from Secretary, December 4, 1900	508.25
Interest on deposits, December 4, 1900	1.08
Total	$648.22

DISBURSEMENTS.

(See Classification)	$635.25
Cash on hand December 4, 1900	12.97
	$648.22

CLASSIFICATION OF EXPENDITURES, 1899-1900.

For expenses prior to annual meeting of 1899	$19.00
For expenses of annual meeting 1899	56.88
For monthly meetings, notices, reports and printing proceedings	90.75
For stationery, postage, etc	56.81
For amendments to Constitution and By-laws, typewriting and printing	42.75
For new bookcase	51.00
For additions to library	4.75
For membership in Association of Engineering Societies	94.75
For rent of 975 Ellicott Square	190.00
For miscellaneous expenses	28.56
Total	$635.25

PERMANENT FUND.

Cash on hand December 4, 1899	$80.00
Total received from Secretary, December 4, 1900	90.00
Interest on deposits	2.36
Total in Erie Co. Savings Bank	$172.36

Condensed by

W. A. HAVEN, *President.*

REPORT OF THE LIBRARIAN FOR THE YEAR 1900.

BUFFALO, N. Y., December 4, 1900.

There has been expended on the library proper during the year the following amounts:

Bookcase	$51.00
Engineering Magazine	3.00
Engineer (London)	8.50
Water and Gas Review	.95
Cassier's Magazine	2.75
Topographical maps of New York State	2.00
Table of altitudes	.40
Engineering indexes	5.45
Temporary binding	4.75
Total	$78.80

Received for old bookcase $50, making a net expenditure of $28.80.

Additions to the library other than by purchase are as follows:

Exchanges	123	numbers.
Donations—Reports, etc.	433	"
Catalogues	23	"
Total	579	"
Periodicals, purchased as above	88	"
Total additions during year	667	"

This library is becoming more valuable each day for reference purposes, and in order that the material on hand may become properly available it is indispensable that a substantial appropriation be made each year for binding and for additional bookcases, as well as for current literature We need at present $50 for binding periodicals, etc., an an equal amount for bookcases.

An unfortunate feature in connection with our exchanges is that we have but little to offer Societies which publish their own proceedings, and are supplied from other sources with the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. As a result we have lost one valuable exchange during the past year.

The Society is especially indebted to Mr. John C. Trautwine, Jr., for a copy of "The Civil Engineer's Pocket Book," to Mr. George W. Rafter, for papers and reports, to Mr. Charles H. Tutton, for periodicals, and to Mr. Horatio A. Foster, for books and maps.

Respectfully submitted,

J. A. KNIGHTON, *Librarian.*

Louisiana Engineering Society.

THE regular meeting of the Louisiana Engineering Society was called to order on Monday, December 10, 1900, at 8 o'clock, by President Malochee, with thirty-eight members and fifty-five guests present.

The minutes of the last meeting of the Society were read and approved. The minutes of the meeting of the Board of Direction on December 8, 1900, were read for the information of the Society.

The monthly statements of the Secretary and of the Treasurer were read and approved. They showed a balance on hand of $326.17.

Chairman Kerr, of the Auditing Committee, made a verbal report, in which he called the attention of the members to the considerable sum it was necessary to pay to the collector, and requested the members to save

this amount to the Society by paying in their dues promptly upon receipt of the quarterly bills. Mr. Kerr's verbal report was received and approved.

The Library Committee submitted a written report (see Secretary's file) stating that ten more volumes of the back numbers of our periodicals had been sent to the binder, and that a handsome cypress case for the periodicals had been made and placed in the library. The committee also asked for authority to renew the subscriptions to all the periodicals now on our list, substituting the *Iron Age* for the *Army and Navy Journal.* The committee suggested that a monthly appropriation be made for the purpose of purchasing new books. The report was received and referred to the Board of Direction with full power to act.

Chairman Tutwiler, of the committee appointed to recommend the best method of discussing the papers appearing in the JOURNAL, in accordance with the request of Mr. James Ritchie, chairman of Board of Managers of the Association of Engineering Societies, made a written report recommending that, though Mr. Ritchie invited the individual members to discuss the papers, our President be authorized to select the paper to be discussed, and have the Secretary send the members, with the notices of the meeting, a notice of the selection of said paper for discussion, in order that those wishing to do so could prepare for the discussion. These discussions upon the floor to take place whenever the regular meetings of the Society were not entirely taken up with the Society's own transactions. After the discussion the President is to appoint some member present, who is specially fitted to do so, to take up the discussion and publish it in the JOURNAL. The committee further recommended that the Secretary be instructed to send a circular letter to the members informing them of Chairman Ritchie's invitation. The report was received, and its recommendations approved.

The nomination of officers for 1901 was declared in order, and a motion was passed that three tellers be appointed by the President to poll the votes. In accordance with the By-laws two names were balloted upon for nomination to each office. Messrs. DeBuys, Wright and A. Raymond were appointed tellers, and upon the first ballot they announced that Mr. Alfred F. Theard and Major Frank M. Kerr had been nominated for the Presidency. The balloting for Vice-President, etc., had commenced when a motion to adjourn was passed.

Then commenced a jolly smoker which lasted until midnight.

GERVAIS LOMBARD, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 7, 1900.—Called to order at 8.30 P.M. by President Percy.

The minutes of the last regular meeting were read and approved.

Mr. Wolf, member of the Committee on Binding Journals, reported what had been done in the matter of searching out the various periodicals and making a list of missing numbers. Further time was asked and granted.

The following committee was appointed by members present for the purpose of nominating a list of officers of the Society for the year 1901: C. E. Grunsky, J. H. Wallace, Hubert Vischer, Luther Wagoner and G. A. Wright.

The Secretary was instructed to notify these members of their appointment.

The following applications for membership were made:

For members—Harris D. Connick, civil engineer, of San Francisco, proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern; John J. Hollister, civil engineer, of Santa Barbara, Cal., proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern; Norman B. Livermore, civil engineer, Board of Public Works, San Francisco, proposed by Luther Wagoner, Edw. F. Haas and Otto von Geldern.

Mr. George W. Dickie read a paper on the subject of "The Need of Education of the Judgment in Dealing with Technical Matters," which was discussed at length.

Adjourned. OTTO VON GELDERN, *Secretary.*

DEATH OF PRESIDENT GEORGE W. PERCY.

THE President of the Technical Society of the Pacific Coast, Mr. G. W. Percy, died in Oakland, Cal., on December 14, 1900. His death, due to heart trouble, came as a sudden surprise to all, for he had been at his office on the day preceding his death, and had presided at a meeting of the Society a few days before the sad news came that the name of its genial President had to be stricken from the roll forever.

Funeral services were held on Sunday, the 16th, attended by the members of the Technical Society, as well as by many other representatives of the technical professions.

Mr. Percy was one of the foremost architects of California, having built some of the largest and finest buildings in San Francisco. The JOURNAL contains several professional papers from his pen on architectural subjects.

His death is a great loss to the Society, whose staunch friend and supporter he had always been.

In proper time a suitable memorial to his name will be drawn and sent to the JOURNAL for publication.

Mr. Percy was born in Bath, Me., and was fifty-three years old at the time of his death.

Engineers' Club of St. Louis.

514TH MEETING, NOVEMBER 7.—The meeting was called to order at 8.30 P.M., at the Office Men's Club, with President W. S. Chaplin in the chair. Twenty-seven members and eighteen visitors were present. The minutes of the 513th meeting were read and approved. The names of Frederick P. Spaulding, Francis J. Llewellyn and Warren A. Tyrell were proposed for membership in the Club. A letter was received from Monsieur G. Eiffel, the distinguished French engineer, announcing the gift of two volumes on a scientific subject, of which he is the author. A communication was received from the Association of Engineering Societies, extending a general invitation to members of the Engineers' Club to discuss any of the papers appearing in the JOURNAL, the discussion to be forwarded to the Secretary of the Association not later than three months from the date of publication of the paper.

The paper of the evening was on "The Steel Skeleton Construction of a High Office Building," by Mr. J. S. Branne.

Mr. Branne explained the origin and development of steel construction for high office buildings. He discussed the steel construction from the structural engineer's standpoint and exhibited various elevations, sections and floor plans. The paper treated of the foundations, floors, columns, wind bracing and typical details of a high office building.

The discussion was participated in by Messrs. Chaplin, Borden, Fay and Johnson.

Meeting adjourned. F. E. BAUSCH, *Secretary.*

515TH MEETING, NOVEMBER 21, 1900.—The meeting was called to order at 8.15 P.M., 1600 Lucas Place, with President W. S. Chaplin in the chair. Thirty-one members and nine visitors were present. The minutes of the 514th meeting were read and approved. The minutes of the 299th meeting of the Executive Committee were read. The names of Frederick P. Spaulding, Francis J. Llewellyn and Warren A. Tyrell were balloted for and unanimously elected.

A motion was made and carried to decline with thanks the proposal of the Office Men's Club to provide for Club quarters at a stipulated rental in its building, 3022 Olive street. It was moved and the motion unanimously carried that a committee of five be elected to form a committee on nominations for officers for the ensuing year. The five members so elected were Messrs. Ockerson, Hermann, Moore, Flad and Colby.

On motion of Mr. Pitzman, the motion being duly carried, the Chair appointed a committee of five—viz, Messrs. J. Pitzman, E. J. Spencer, William Bouton, H. H. Humphrey and A. H. Zeller—to solicit further subscriptions, increasing the Engineers' Club share of contribution to the World's Fair funds.

The Secretary was instructed to draft a letter to be mailed to members explaining the need of an increased subscription, inclosing also a blank form returnable to Mr. J. Pitzman.

The allotment to the Engineers' Club for World's Fair aid is $15,000. It is hoped that this sum will be promptly met and that the members will, individually, take an active interest.

The paper of the evening was on "Street Lighting of Cities," by Mr. H. H. Humphrey. The question of proper illumination of streets in a large city was thoroughly reviewed, the speaker referring to the recent developments in street illumination in St. Louis with a view to adopt a uniform and diffused light in preference to the one, as he expressed it, which gives brilliantly lighted crossings and Egyptian darkness in the middle of the blocks. The developments appear to be along the lines of the inclosed arc lamps and the improved mantle gas lamps quite familiar to St. Louisans. Comparisons were made between the direct-current series inclosed arc and the alternating series inclosed arc. The comparative difference in candle power of the two lamps with the same consumption of energy being unquestioned, the former lamp was adopted in connection with the new lighting contract. The city required 480 watts at the arc regardless of the candle power, but thanks to the engineers of the plant, at least in this instance, they give the public the benefit of the 16 per cent. increase in light.

A general description of the new city lighting plant was given with a discussion of its principal engineering features, also a data sheet giving a test of one of the units and some data obtained from a test of another high-voltage plant.

A number of slides in connection with the city lighting plant were exhibited.

The discussion of the paper was participated in by Messrs. Humphrey, Flad, Kinealy, Bouton, Spencer, Roper, Reber and Hermann. The meeting adjourned to an adjoining room, where lunch was served.

F. E. BAUSCH, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., DECEMBER 19, 1900.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 P.M.; President Alexis H. French in the chair. Eighty-four members and visitors present.

The record of the last meeting was read and approved.

Messrs. William L. Blossom and Walter H. Sawyer were elected members of the Society.

The thanks of the Society were voted to Alexander Martin, agent of the Cunard Steamship Company, Limited, and to Captain Pritchard and Chief Engineer MacFarlane, of the "Saxonia," for courtesies extended on the occasion of our visit to the steamship "Saxonia" on Thursday, December 6; also to the New England Electric Vehicle Transportation Company for courtesies extended to us this afternoon on the occasion of our visit to its plant.

Mr. Albert S. Cheever read the first paper of the evening, entitled "Stone Arch Bridges Recently Constructed on the Fitchburg Railroad." Mr. James W. Rollins, Jr., followed with a paper on "Arch Centers." Both papers were profusely illustrated by lantern views.

Adjourned. S. E. TINKHAM, *Secretary.*

Montana Society of Engineers.

AT a special meeting of the Society held on November 24, Butte was selected as the place for holding the annual meeting, and the dates January 10, 11 and 12, 1901. President Blackford appointed the following committees:

On Transportation—H. W. Turner.

On Arrangements—R. A. McArthur, E. H. Wilson, G. W. Tower, Jr., C. H. Moore and Eugene Carroll.

THE regular meeting was held on December 8, 1900; President Blackford in the chair. Seven members present. Charles H. Bowman and George T. Ingersoll, both of Butte, were elected to membership.

The Committee on Transportation for the annual meeting reported that the Northern Pacific Railroad and the B. A. and P. Ry. Companies had replied to his request for a single fare for members and visitors to the annual meeting, and both had kindly granted the same. The Great Northern and the Oregon Short Line Companies had not yet replied owing to short time, but he had been assured that the answers would be satisfactory.

The Committee on Arrangements reported progress, and promised to issue a preliminary program of the meeting in a few days. There being no further business, the meeting adjourned.

ROBERT A. MCARTHUR, *Secretary.*

Engineers' Society of St. Paul.

St. Paul, Minn., December 3, 1900.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 p.m. Present, seven members and one visitor. President Powell in the chair. Minutes of previous meeting read and approved.

Mr. George S. Edmondstone and Mr. Noah Johnson were elected to membership.

No paper or discussion preceded adjournment.

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